RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA

VOLUME L

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] **1919.** **[June.**

GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1918. BY H. H. HAYDEN, C.S.I., C.I.E., F.R.S., *Director, Geological Survey of India.*

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DISPOSITION LIST.

1. During the period under report, the officers of the Department were employed as follows :—

Superintendents.

MR. E. VREDENBURG	At headquarters as Palæontologist throughout the period.
DR. L. L. FERMOR	Returned to headquarters on 23rd April 1918. Services placed at the disposal of the Indian Munitions Board during the following periods— from 20th May to 13th June 1918, from 8th July to 3rd August 1918, from 29th October to 7th November 1918.
	On privilege leave from 21st to 28th October 1918. At headquarters from 15th November 1918.
DR. E. H. PASCOE	Returned to headquarters on 19th January 1918. Deputed to Mesopotamia and left for the field on 5th November 1918.

Assistant Superintendents.

DR. G. E. PILGRIM .	On deputation in Persia throughout the year except for a brief period from 24th March to 22nd April 1918.
MR. G. H. TIPPER .	Employed in the mica-mining area of Hazaribagh.
MR. H. WALKER .	Returned from the field on 18th April 1918. Appointed Curator with effect from 27th October 1918.

MR. K. A. K. HALLOWES Returned to headquarters on 13th April 1918. Posted to Burma and left headquarters on 30th October 1918.

MR. G. DE P. COTTER At headquarters as Curator up to 26th October 1918. Examined dam sites on the Usri and Barakar rivers, near Giridih from 17th to 21st April 1918. Deputed to examine the kaolin of Kasumpur, Delhi, and the soda deposits of Sind and left for the field on 26th October 1918.

MR. J. COGGIN BROWN Employed in Tavoy in connection with the wolfram mining industry.

MR. H. C. JONES Returned to headquarters on 13th February 1918. Posted to Burma to examine the antimony deposits of the North Shan States and left headquarters on 25th February 1918. Returned from Burma on 2nd August 1918. From 1st November 1918 engaged in examining dam sites in Saugor and Bilaspur districts, Central Provinces and iron ore deposits in Singhbhum.

MR. A. M. HERON Employed in Tavoy in connection with the wolfram mining industry.

DR. M. STUART Returned from Burma on 3rd June 1918. Engaged from 17th July to 9th August 1918 in investigating the area affected by the Srimangal earthquake of 8th July 1918. Deputed to examine limestone deposits in various parts of India and left headquarters on 24th November 1918.

Mr. C. S. Fox . .	Completed on the 19th April 1918 the investigation of bauxite deposits in Chota Nagpur; was placed in charge of Jorasimar mica mine, Hazaribagh, with effect from 30th April 1918.
Mr. R.W. Palmer	On military duty.

Chemist.

Dr. W. A. K. Christie	Services placed temporarily at the disposal of the Government of India in the Finance Department with effect from 12th April 1918.

Artist.

Mr. K. F. Watkinson	At headquarters. Granted privilege leave for one month and 22 days from 2nd December 1918.

Sub-Assistants.

Mr. S. Sethu Rama Rau.	Returned from the field on 8th May 1918. On privilege leave from 1st to 8th October 1918. Posted to Tavoy and left headquarters on 22nd October 1918.
Mr. M. Vinayak Rao.	Returned from the field on 16th May 1918. Granted privilege leave for one month and four days from 5th September 1918. Posted to Tavoy and left headquarters on 30th October 1918.

Assistant Curator.

Babu Bankim Behari Gupta.	Appointed on the 26th August 1918 at headquarters.

ADMINISTRATIVE CHANGES.

Promotion and appointments.

2. Dr. G. E. Pilgrim officiated as Superintendent from 20th May to 13th June 1918, from 8th July to 3rd August 1918 and from 21st October to 7th November 1918, *vice* Dr. L. L. Fermor, on deputation to the Indian Munitions Board.

Mr. H. Walker was appointed Curator with effect from the 27th October 1918.

Babu Bankim Behari Gupta was appointed Assistant Curator with effect from the 26th August 1918.

Leave.

3. Dr. L. L. Fermor was granted privilege leave from the 21st to 28th October 1918.

Mr. K. F. Watkinson was granted privilege leave for one month and 22 days with effect from 2nd December 1918.

Mr. Sethu Rama Rau was granted privilege leave from the 1st to the 8th October 1918.

Mr. M. Vinayak Rao was granted privilege leave for one month and four days with effect from the 5th September 1918.

MILITARY SERVICE.

4. Only Mr. R. W. Palmer remained in the Army throughout the year, all other members of the Department having been recalled for civil duty. Lt. Colin Campbell, whose services have been lent to the Geological Survey by the military authorities, remained with this Department throughout the year.

STUDENTS.

5. Babu Harendra Mohan Lahiri, M.Sc., post-graduate scholar, continued to carry on research work in the Museum and Laboratory throughout the year.

PROFESSORSHIPS AND LECTURERSHIPS.

6. On proceeding to the field in October, Mr. G. de P. Cotter was relieved by Mr. H. Walker in his appointment as Lecturer on Geology at the Presidency College, Calcutta.

Mr. E. Vredenburg continued to act as a Professor of Geology at the Calcutta University, in addition to his own duties, throughout the year.

LIBRARY.

7. The additions to the library amounted to 1,887 volumes, of which 726 were acquired by purchase and 1,161 by presentation and exchange.

PUBLICATIONS.

8. Owing to pressure of work, it has been found impossible to issue the usual number of publications during the year: only three parts of *Records* Volume XLIX, were published, the fourth part standing over till the beginning of the new year. The issue of a very important work, however, was completed; in 1917, the first part of the new Bibliography of Indian Geology and Physical Geography, compiled by Mr. La Touche, was published, while the second part, consisting of an Annotated Index of Minerals of Economic Value, was issued during the year under review. This work is already in considerable request, and should prove of great value to those interested in the economic development of the country. One memoir of *Palæontologia Indica* (New Series, Vol. III, No. 2) dealing with the Brachiopoda of the Namyau beds, Northern Shan States, was also issued during the year.

MUSEUM AND LABORATORY.

Staff.

9. Mr. G. de P. Cotter was Curator of the Geological Museum and Laboratory from the beginning of the year until the end of October, when he left Calcutta for field-work in Sind. Mr. H. Walker took charge of the duties for the remainder of the year. Mr. A. K. Banerji was Assistant Curator until the 26th August, on which date he was transferred to the post of Head Clerk. The senior Field Collector, Babu Bankim Behari Gupta, was promoted to Assistant Curator. Babu Baroda Charan Gupta, senior Museum Assistant, was promoted Field Collector.

Chemist.

10. Dr. W. A. K. Christie was Chemist in the Department from the beginning of the year to the 12th April on which day his services were placed temporarily at the disposal of the Government of India in the Finance Department.

11. The number of specimens referred to the Curator for examination and report was 460, of which assays and analyses were made of 93. The corresponding figures for the previous year are 600 and 83. The chemical work included analyses of kaolinite, limestone, coal, wolfram and sulphur-bearing rocks and assays of ores of antimony and lead.

Determinative work and analyses.

12. During the year various specimens of rocks, minerals and fossils were given to :—

Donations to Museums, etc.

(1) The Islamia High English School, Gaibandha (Rangpur).
(2) University College of Science, Calcutta.
(3) The Superintendent, Mayurbhanj State.
(4) St. Mary's Convent, Allahabad.
(5) The Mining Engineer, Gwalior State.
(6) Agricultural College, Poona.
(7) McMahon Museum, Quetta.
(8) Agricultural Museum, Muzaffarpur.

A small collection was sent on loan for the Gwalior State Exhibition

13. The following foreign specimens were added to the collections during the year :—

Additions to the collections.

(1) Asbestos, from the Belingwe District, Rhodesia, presented by Captain L. Ludlow, Bedfordshire Regiment.
(2) Asbestos (chrysotile), from the Goedverwacht mine, Transvaal, presented by A. G. Grimley, Esq.

Amongst the Indian specimens received, the following may be mentioned :—

(1) Allanite, from Bahea, Ranchi District, presented by P. E. Billinghurst, Esq.
(2) Scheelite and wolfram with copper pyrites from the Pagaye mine, Tavoy District, presented by Messrs. The Bombay-Burma Trading Co., Ltd.
(3) Mica from Chauparan, Hazaribagh District, presented by C. C. Augier, Esq.

14. During the year the rearrangement of the show-cases in the fossil gallery has been completed and in all except a few cases new printed labels have been placed in position. The work will be completed early in 1919.

Rearrangement of the fossil gallery.

PETROLOGY.

15. In his account of the geology and coal resources of Korea State, Central Provinces,[1] Dr. Fermor described some puzzling rocks under the name of the Chirmiri volcanic series. Subsequent work on the Bokaro coalfield showed that these rocks were the products of the fusion of shales and sandstone due to the burning of coal-seams at the outcrop.[2] Dr. Fermor has now studied the microscopic aspects of these products and finds them to consist of vitrophyric rocks containing crystals of various minerals in a glassy base, amongst the minerals recognised being cordierite, sillimanite, pyroxenes, plagioclase, black ores, and a mineral closely allied to fayalite. These rocks show the structures and textures of volcanic rocks; but on account of their production from sedimentary rocks with resultant peculiarities in chemical and mineral composition, Dr. Fermor designates them *para-lavas* on the analogy of the terms para-schist and para-gneiss.

PALÆONTOLOGY.

16. Mr. Vredenburg has continued his work on the Tertiary *Gastropoda*, which, however, is not yet complete. He hopes to finish shortly a monograph containing a complete review of the *Cypræidæ* and *Ovulidæ*.

HIMALAYAN STRATIGRAPHY.

17. In my *General Report* for the year 1917 I referred to the supposed discovery at Solan, by Babu Hem Chandra Das Gupta, M.A., of fossils in rocks regarded as of Infra-Krol age. I pointed out at the time that the fossils were badly preserved, and that their determination as Palæozoic brachiopods was not entirely convincing. An opportunity, afforded by a journey to Simla, enabled me to visit the locality; the only fossiliferous rocks observed were of lower Tertiary age, and although the matter can not yet be regarded as definitely decided, my visit confirmed the accuracy of Mr. Medlicott's map, on which the locality in question is shown as lying on Tertiary beds.

18. It is interesting to record the discovery of fossils in the neighbourhood of the Shali peak a few miles to the north of Simla,

[1] *Mem. G. S. I.*, XLI, Pt. 2, p. 138, (1914) and *Rec. G. S. I.*, XLIV, p. 13, (1914).
[2] *Trans. Min., Geol. Inst. of India*, XII, pp. 50-63, (1918).

The locality lies on the ridge running from Matiana to the Shali peak and at about one mile north-west of the village of Barhana. The fossiliferous beds consist chiefly of shaly limestones, and can be traced for over a mile or more to the N. N. E. along the ridge towards Kanda Devi. The fossils are extremely badly preserved, but have a general Upper Mesozoic aspect. They consist chiefly of lamellibranchs, but there are also numerous irregular tubular structures for the determination of which as chætopod worms I am indebted to my colleague, Mr. G. H. Tipper. These annelids belong to the genus *Serpula* and are remarkably like certain Jurassic and Cretaceous forms. So far I have only been able to spend a few hours at the locality, but it is hoped that further examination may yield a better preserved and more characteristic fauna.

ECONOMIC ENQUIRIES.

Antimony.

19. Mr. H. C. Jones visited during the year antimony deposits in Mong Hsu State and also in the neighbourhood of Keng Tung, Southern Shan States. Two localities were visited in Mong Hsu, *viz.*, Loi Hpwe (Nakeng) and Loi Hke. A certain amount of prospecting work has been done by private individuals or by companies on these ore-bodies, but most of the ore hitherto recovered has been obtained from detrital boulders lying on the surface. Most of the workings were inaccessible owing to water. No definite conclusion could be arrived at therefore with regard to the Nakeng deposit, although the fact that the boulders lying on the surface have all been found along a narrow band seems to indicate that the stibnite ore-body is not a large one. Mr. Jones considered that the Loi Hke deposit was not promising.

20. Small quantities of stibnite were also noticed at Hkumhpok and Loisang in the Mong Kung State, where small quantities of ore had been extracted from time to time by the local inhabitants, but the amount available was apparently insignificant.

21. Small quantities of stibnite were noticed in pits in the neighbourhood of the Railway near Lebyin station between Kalaw and Pyinyaung. The stibnite appears to be sparsely distributed through a small vein of fine-grained quartz; it is considered by Mr. Jones to be of no economic value.

22. Mr. Jones also took the opportunity of visiting a locality in Keng Tung State from which specimens of antimony ore had been sent to this Department. The ore occurs near the village of Mong Ing, which lies in the hills about 25 miles south of Tongta, 241 miles from Taungyi on the road to Keng Tung. The deposit is a small stibnite vein or pocket in limestone, and is too small in extent and too poor in quality to hold out any hopes of successful working.

Apatite.

23. Although the magnetite-apatite-rocks of Singhbhum contain on the average more apatite than magnetite they are for the sake of convenience referred to under Iron (p. 14).

Chromite.

24. The discovery of chromite at the Suru Pass in the Kolhan in Singhbhum was recorded some years ago.[1]

Singhbhum.

During succeeding years numerous small deposits of chromite have been discovered in the same country, leading to the export during the past few years of some 8,000 tons of chromite. In March and April, 1918, Dr. Fermor re-visited this area and prepared a map of the occurrences on a scale of 4 inches to the mile. Three separate patches of peridotite give rise to prominent hill masses known respectively as Kimsi Buru, Kitta Buru, and Chitung Buru-Roro Buru, and these are surrounded by a comparatively little metamorphosed Dharwar terrane of slates, slaty shales, and quartzites, with occasional thin bands of limestone. The ultrabasic rocks appear to be laccolitic intrusions several hundred feet thick that have participated in the later stages of folding of the Dharwars. The component rocks have been much altered, but were originally saxonite, dunite, and subordinate pyroxenite,—saxonite, with fluidal arrangement of pyroxene (enstatite) being the most abundant type; one specimen of lherzolite was also found. These rocks have been very largely serpentinised, so that it is very difficult to find a specimen showing unaltered olivine; but fairly fresh enstatite is common. Chromite occurs almost invariably as scattered grains in the serpentinised dunites, and frequently, but not always, in the altered saxonites.

[1] *Rec., G. S. I.*, Vol. XXXVIII, p. 34, (1909).

In addition bands of ore are found in both serpentinised dunite and altered saxonite. These bands of ore are rarely a foot thick, usually less, but are the source of the chromite exported from this area. The evidence collected proves conclusively, even more satisfactorily than in Baluchistan, that the chromite bands are of primary (magmatic) origin, contemporaneous with the dunite and saxonite.

25. Whereas the chromite deposits of Baluchistan usually take the form of irregular masses or lenses, rendering it difficult to make reliable estimates of quantity of ore available, the Singhbhum deposits are definite bands, which in some cases have been traced by quarrying operations for thousands of feet. Thus on the east side of Inde Buru (a portion of Roro Buru) and the south slope of Chitung Buru, one band of ore has been traced at intervals for over a mile, the interruptions being due to numerous small cross faults. This ore-band is sometimes single and from 7 to 10 inches thick, but in other places it is split into several thin bands of about the same aggregate thickness, but distributed through a total thickness of 1½ of 2 feet to rock.

26. The alteration of these peridotites has not always resulted in the production of serpentine. At or close to the margins, talc-slates or schists have almost always been formed, but in places schistose serpentine is found. Further, the thin tongues of ultrabasic rock, where the effects of folding have been most intense, have usually been converted entirely into talc-rocks.

27. The formation of the Singhbhum serpentine appears to have been effected by the action of siliceous solutions, for the occurrences are characterised by the absence of magnesite and by the formation of great quantities of chert, usually along the margins of the ultrabasic masses, but sometimes as dyke-like streaks penetrating the serpentinous rocks, as in Chitung Buru. These cherts have been formed by the replacement of the magnesian rocks and reveal their origin, both by their position, their structures, and their residual enclosed chromite grains. Where the magnesian rocks are free from chromite, the adjacent cherts are found to follow suit.

28. Too strong emphasis cannot be laid on the chemical stability of chromite in nature. Chromite-bearing magnesian rocks have been replaced by silica with formation of chrome-cherts; in one place later carbonate solutions have attacked the cherts with

replacement to a marble still containing unaltered chromite grains, giving, in fact, a chromite-marble. Subsequent siliceous solutions have veined this rock with quartz.

29. As regards economic prospects the chromite deposits of the Kolhan may be stratigraphically continuous to as great depths as the enclosing ultrabasic rocks, but the thinness of the chromite bands and the numerous small faults will render it economically impracticable to resort to underground mining, so that the industry will probably cease as soon as all the ore that can be extracted by opencast methods has been removed. At present only first-grade ore is removed, but the possibility of treating in concentration mills low-grade ores containing not less than 10 per cent of Cr_2O_3, as in Canada, may one day be worth consideration, especially if future prospecting should lead to the discovery of additional peridotite massifs in the unexplored portions of the Kolhan to the south.

30. Numerous veins of chrysotile, some of which appears to be of good quality, have been found in some of the chromite excavations.

Coal.

31. A considerable amount of interest was aroused in Burma during the year by reports of the discovery of valuable coal-seams on the flanks of the Arakan Yoma near Minbu and in the Northern Shan States. The Geological Survey was called upon to investigate the matter. On enquiry it was found that the reports with reference to coal in the Northern Shan States referred to the Namma and Lashio fields, which had already been examined by Messrs. La Touche, Simpson and Brown of the Geological Survey some years ago. More extended prospecting operations have, as might have been expected, resulted in an increased amount of fuel being shown to be available. The material in question, however, was shown by Mr. Simpson to be a lignite of poor quality; it was found unsuitable for locomotive purposes, while its lack of coking qualities has rendered it hitherto unsuitable for metallurgical purposes. The advances that have recently been made in the employment of inferior coals in the pulverised form may possibly provide use for these lignites of the Shan States, but even if the conditions of exploitation and distribution prove favourable, their use will probably be restricted.

32. In consequence of promising reports on the coal found in the foot-hills to the west of Minbu, Mr. K. A. K. Hallowes was deputed to examine the seams. It had been stated that locomotive trials on a bulk sample had shown the coal to be not greatly inferior to Bengal steam coal, and it was hoped that it might be possible to reduce the cost of transport sufficiently to make successful competition with the latter possible. Unfortunately, however, the so-called bulk sample proved to be a carefully hand-picked specimen which represented merely a band of two or three inches of fairly pure lignite occurring in the middle of a seam of extremely inferior quality containing from 13 to 26 per cent. of moisture and 14 to 30 per cent. of ash. The seams themselves also proved to be typical of all the lignite occurring on the eastern flanks of the Arakan Yoma and to be merely small lenticular patches extending, as a rule, for only a few hundred feet.

Engineering Questions.

33. A large number of sites for dams were examined during the year on behalf of various Local Governments. Mr. H. C. Jones reported on five sites in the Saugor and Bilaspur districts of the Central Provinces. Mr. Walker reported on the foundations of the Lake Arthur Hill dam at Bhandardara in the Bombay Presidency, and Mr. Cotter examined sites in connection with proposed reservoirs on the Usri and Barakar rivers.

Gold.

34. During the course of his investigation of the mineral resources of Putao district in Upper Burma, Dr. Stuart examined some small alluvial workings for gold on the banks of the Nmai Hka about half a mile below the confluence of the Nam Tamai and the Taron. The workings proved to be small and of no particular economic value. Other workings are reported to be found in the Akyaung valley, where nuggets of fair size are said to have been obtained; but as the locality is extremely inaccessible and the information available very scanty and unreliable, it was considered advisable to postpone the investigation of the Akyaung valley until further information had been collected.

Iron.

Hematite deposits, Singhbhum.

35. Some years ago the Bengal Iron Steel Co., Ltd., secured two deposits of iron-ore in Saranda (Singhbhum) forming parts of two large hill masses known as Notu Buru and Buda Buru respectively. During the past two years further prospecting in this part of Singhbhum has led to the discovery of numerous additional deposits of iron-ore, the extension of which has been traced into Keonjhar and Bonai States in Orissa. a total distance of some 40 miles in a S. S. W. direction. On account of the reports from various sources of the large supplies of iron-ore thus found Dr. Fermor paid a visit to the Bengal Iron & Steel Co.'s mine at Pansira Buru, a portion of Notu Buru, the only deposit yet opened up, and the one that now feeds the Barakar ironworks. Pansira Buru rises to over 2,500 feet above sea-level, the low ground on the west side being at about 1,100 feet above sea-level. The uppermost 400 to 450 feet of this hill has now been opened up, and the workings indicate the existence of a deposit about a quarter of a mile long, perhaps 400 feet thick and proved on the dip for about 500 feet. The ore-body appears to be interbedded with the Dharwar slates, from which it is separated by banded hematite-jaspers. The ore itself is high-grade micaceous hematite, often lateritised at the outcrop. Cross-cuts into the interior of the deposit show that the hematite becomes very friable not far below the outcrop. In fact the characteristics of this ore, including the surface lateritisation, are almost exactly reproduced in the iron-ore deposits of Goa and Ratnagiri, and this agreement serves to confirm Maclaren's correlation of the Singhbhum "sub-metamorphics" with the Dharwars of Southern India.

36. At the end of the year Mr. H. C. Jones commenced a more detailed examination of the iron-ore ranges in Saranda.

Magnetite-apatite deposits, Singhbhum.

37. The existence of apatite-magnetite-rocks at Patharghara and Musaboni in Dhalbhum has been known for some years,[1] and deposits have now been located along a belt stretching for 12 miles in a direction S. 37° E. from Patharghara to Khejurdari, and included in concessions secured by the Bengal Iron & Steel Co., Ltd., for iron-ore, and by the Great India Phosphates Limited for apatite.

[1] *Rec., G. S. I.*, Vol. XXXVI, p.128, (1907).

An opportunity was taken this year of deputing Dr. Fermor to make a study of these occurrences. He finds that the magnetite-apatite-rocks occur as lenses in the Dharwar schists parallel to the strike and varying in size from 90 feet long by 24 feet thick in the middle, through lenses 2 feet or 3 feet by 1 foot down to lenticles a few inches long, and then to separate granules and crystals disseminated in the associated schists. As a rule apatite is the predominant mineral. The apatitic belt coincides roughly with the belt of old copper workings and the introduction into the Dharwar schists of the apatite, magnetite, and chalcopyrite has been accompanied by chloritisation of the schists. It was anticipated that the magnetite-apatite rocks would prove to be igneous introductions analogous to the apatitic magnetite ore-bodies of Lapland, but the facts prove to be better explained by regarding the magnetite-apatite rocks as due to pneumatolytic introductions from the Singhbhum granite. Where they occur together the chalcopyrite seems to be later than the magnetite-apatite rocks and may be referred to a later hydrothermal phase of activity. The apatite itself seems to be slightly earlier than the magnetite. At one locality (Sunrgi) incrustations of uranium mica are found on the magnetite-apatite rocks, but the primary uranium mineral has not yet been detected.

Pal Lahara.

38. During his visit to Pal Lahara State to examine mica deposits Dr. Fermor obtained specimens from the mountain mass known as Malayagiri (3,895 feet) which he was unable personally to visit, proving the existence, hitherto unsuspected in this part of Orissa, of hematitic quartzites of Dharwar aspect. Amongst the specimens was some high-grade micaceous hematite, pointing to the desirability of examining this part of Orissa for still another iron-ore field.

Kaolin.

39. At the request of the Chief Commissioner, Delhi, Mr. G. de P. Cotter visited the kaolin quarries at Kasumpur and submitted a report.

40. At the request of the Local Government, Mr. Hallowes has been employed in Burma in examining reported deposits of kaolin in Pakokku and Yamethin. The investigation had not been completed at the end of the year.

Lead.

41. In consequence of the reported occurrence of large quantities of lead slag in the district of Putao, which has recently been brought under the administration of the Government of Burma, the Local Government asked that a member of the Geological Survey should investigate the mineral resources of that district. Dr. Murray Stuart was detailed for the work, and spent the greater part of the field-season in Putao and the neighbouring valleys. He found the reports regarding the lead slag to have been exaggerated; the total quantity seen by him during the whole of his tour did not amount to more than about a ton, while the veins from which the lead-ores had originally been won were merely thin stringers of no possible economic importance.

Mica.

42. The demand for mica continued throughout the year. Mr. G. H. Tipper was in charge of the Bihar and Orissa party, and devoted most of his attention to the Hazaribagh district, including the Kodarma forest, where he was frequently called upon for advice and assistance by the local district officers, as well as by the mining community. He also did a considerable amount of geological work in the neighbourhood of Mahesri in Monghyr district, where his investigations proved of great assistance in the subsequent mining operations.

43. Two mica-bearing properties in the province of Bihar and Orissa, which were lying idle owing to litigation, were taken over by the Local Government under the Defence of India Act. The larger of the two was handed over to a commercial firm to be worked on behalf of the Government, and, owing to the difficulty of finding mining engineers, it was arranged that the services of Lieutenant Colin Campbell, at present attached to the Geological Survey, should be made available for the supervision of the mining operations in that area. Mr. Campbell threw himself into the work with the greatest enthusiasm and energy, and prepared for development on a large scale; and although his operations were seriously hampered by rain and cholera, he succeeded ultimately in bringing his output up to 90 maunds of rough mica, equivalent to over ½ ton of cut mica, per diem.

44. The second property taken over by the Government of Bihar and Orissa is situated in the *gadi* Masnodih. It was worked first under the direct supervision of the Local Government, but was subsequently handed over to the Geological Survey. The property is a small one, but has been developed during the last few months with great success by Mr. C. S. Fox, whose work deserves high praise.

45. The occurrence of mica in Udaipur State was referred to in the *General Report* for last year, in which it was stated that the attention of the Udaipur Darbar had been drawn to the promising nature of the pegmatites. Unfortunately, however, no immediate steps were taken by the Durbar for their development but, after prolonged negotiations a lease was granted to Messrs. Chrestien and Dadabhoy for the joint working of the property.

46. Attention was also directed during the year to the Travancore phlogopite, small quantities of which had been extracted and exported in the past, and one of the leading firms engaged in mica-mining in India has now opened up negotiations with the Travancore Durbar for the development of the properties.

Soda.

47. From the end of November 1918 till the beginning of February 1919, Mr. G. de P. Cotter was engaged in examining the carbonate of soda (*chaniho*) deposits of Sind. These are distributed over two areas, the first being a belt of country about ten miles in breadth, bisected by the channel of the Eastern Nara river, and lying between latitudes 26° 47′ and 26° 5′, and the second area being a tract near the border of Sind and Jaisalmir, lying between latitudes 26° 21′ and 26° 30′, and longitudes 69° 40′ and 69° 55′. The first area lies mainly in the Khairpur State and the Nawabshah (formerly called the Nasrat) taluqa of the Nawabshah district, but includes a small portion of the Sanghar taluqa of Thar and Parkar district. The second area lies entirely in the Khairpur State west of the old fort known as Kot Jubbo. Both these tracts are covered with hills of desert sand, under which is concealed the old alluvial soil, which in the exposed portions is full of *reh* or *kalar* efflorescence. The rain water which sinks through the sand is held up by the old alluvial soil underneath, and flows horizontally underneath the sand, emerging in any low lying places or hollows in the sand hills where the

alluvial soil is exposed or close to the surface. Here shallow lakes are formed, locally known as *dhands*. The water of these *dhands* is continually being supplied with the soluble salts of the soil and sub-soil, so that eventually they contain concentrated solutions of whatever salts are in the soil. In the areas above named carbonate of soda is the predominant salt, with lesser portions of chloride and sulphate. In other parts of Sind the chloride predominates. The lakes are at their highest concentration in the early summer just before the rains, and it is then that most of the *chaniho* is collected. An analysis made of the *chaniho* clearly shows that it is the same mineral as trona or urao, (Na_2CO_3. $NaHCO_3$. $2H_2O$). Only those lakes which are very shallow (usually 1 to 3 feet deep), and which thus form natural evaporating pans, are worked for *chaniho*. There are however many *dhands*, which are over 3 feet deep, which never become sufficiently concentrated to deposit *chaniho*. Mr. Cotter is of opinion that, provided that the price of soda does not fall considerably as a result of the development of the Magadi deposit in British East Africa, it would be profitable to work the larger *dhands*. The quality of the urao obtained from those at present worked might also be much improved by the intelligent use of hydrometers. Chatard has shown that the concentration should not be allowed to pass a specific gravity of 1·280 (*Bull., U. S. Geol. Survey* No. 60, p. 65). As no attention is now paid to this point, and as the *dhand* is sometimes allowed to dry completely before any *chaniho* is collected, the mineral is contaminated by the presence of the impurer fractions which are deposited after the urao, and thus it contains large or small quantities of chloride or sulphate according to the original composition of the solution. The traffic in *chaniho* in the Sanghar and Khipro taluqas of Thar and Parkar district was put down by the Salt Department in 1902, because the product put on the market contained more than 50 per cent. of chloride, and was therefore dutiable.

48. A portion of the *chaniho* is sold in the bazaars of Hyderabad and Karachi, and is used in washing, dyeing, cookery, etc. The main portion is exported, the export figures for 1916 being 14,519 cwt. valued at Rs. 87,116, or Rs. 6 per cwt. The amount produced might be considerably increased, doubled or possibly trebled, if the larger *dhands* were worked by means of constructing "soda gardens" near their margins, and allowing the solution to concentrate by solar evaporation. The amount of soda annually produced

will never be very great, and is not likely to exceed four or five thousand tons.

Sulphur.

49. Dr. Pilgrim completed his examination of the sulphur mines at Linga and Bostanah in the Persian Gulf, but, owing to his absence from headquarters in connection with other investigations, he has not yet been able to submit his report. The samples collected by him from the above deposits yielded, on analysis, sulphur contents ranging from 12 to over 55 per cent.

50. It was not possible to take up during 1918 the re-examination of the old sulphur mines near Sanni in Baluchistan, but this will be completed during the current field-season.

Tin.

51. The Geological Survey Department has frequently drawn attention to the fact that certain alluvial deposits of the Tavoy district carry cassiterite and that their valuation by modern methods of testing was worth undertaking, to prove finally whether the ore can be won from them on a profitable scale or not. It is gratifying to report that considerable attention was paid to the subject by various large firms during the year and that a boring campaign was initiated in several localities.

Tungsten.

Burma.

52. The Geological Survey party continued its work in Tavoy and Messrs. Coggin Brown and Heron remained in Burma throughout the year. In the open season Mr. Heron was employed in geological survey work but during the rains he visited other parts of the province and while in Tavoy assisted Mr. Coggin Brown in his routine duties. These consist in advising the local authorities on matters connected with the mining industry, such as the grant of prospecting licenses and mining leases, water rights, boundary disputes, etc., and in periodical visits to all parts of the field in connection with the upkeep and development of wolfram and tin mining. The Tavoy output for the year amounted to 3,636 tons compared with 3,654 tons in 1917. The small decrease is attributed to the severe influenza epidemic of October and November. Mr. Coggin Brown continued

to act as a member of the Mining Advisory Board and as Inspector of Mines.

Singhbhum.

53. The small deposit of wolfram being worked near Kalimati in Singhbhum was visited by Dr. Fermor in April. The wolfram has been obtained from pockets on the surface of a bed of Dharwar quartzite overlain by muscovite-quartz-schist and dipping 42° to N. 35° E. The quartzite contains some interbedded veins of quartz, and the introduction of the wolfram was probably connected with the formation of these veins. The wolfram has been followed to a depth of 108 feet from the surface and was still in evidence at this depth at the bottom of an inclined shaft.

GEOLOGICAL SURVEYS.

Burma.

54. It was not possible to resume systematic survey operations during the year 1918 except in Tavoy and neighbouring districts, where such operations had a direct bearing on the output of wolfram. Mr. J. C. Brown remained in charge of the Tavoy party. He was not able to take any active part in the surveys, but Mr. Heron and Messrs. Sethu Rama Rau and M. Vinayak Rao continued the survey of the Tenasserim province on the scale of 1″=1 mile. Sufficient material has now been collected for the publication of a geological map of Tavoy on the scale of 1″=4 miles, and this is now in the hands of the Survey of India Department for reproduction. Mr. Heron has completed large-scale geological maps of some of the chief mines of Tavoy using as a basis the mine-plans kindly put at his disposal by the companies concerned.

Orissa.

55. In his tour through the Orissa Feudatory States in the winter of 1917-18 in search of mica, Dr. Fermor was enabled to visit a tract of India much of which had not been previously traversed by a geologist. The brief examination thus rendered possible of the Archæan rocks over a wide tract of country showed that from the geological point of view Orissa must be regarded as a composite province, the northern portion being related to Chota Nagpur and the southern to the Eastern Ghats.

56. Throughout Sonpur, Baudh, the western end of Daspalla, in southern Rairakhol, Athmallik and southern Angul, and in Hindol and Dhenkanal, nearly all the varieties of Archæan rocks

are rich in garnet, and in addition to porphyritic garnet-gneisses and garnet-granulites, khondalite ranges occur. Such rocks are also known to occur in Kalahandi and west of Borasambar, and of course are amongst the chief constituents of the Eastern Ghats. In the area now referred to they extend, approximately, as far north as the southern edge of the Talcher coalfield.

57. On the north side of the Talcher coalfield, as seen in Talcher and Pal Lahara States, and in Bonai State further to the north, the rocks are of a totally different facies, the gneisses being as a rule devoid of garnets, whilst instead of the khondalites we have high ranges of schistose sericitic quartzites, with sericite and mica-schists and hematitic quartzites, in fact rocks of a Dharwarian facies. The entire facies is indeed, reminiscent of Singhbhum.

58. Using garnet as an index Dr. Fermor regards the Eastern Ghats as a portion of the crust that has been subjected to more intense metamorphism than Chota Nagpur. But it must be left to future research to decide whether the differences between these two regions are entirely a function of dynamic history or whether there were also original differences as regards composition both stratigraphical and mineralogical. Whatever the relative ages of the rocks of these two regions, however, the deduction that the rocks of the Eastern Ghats facies have been subjected to a more intense grade of metamorphism than those of Chota Nagpur indicates, according to Dr. Fermor, the existence between the two regions either of some form of shear or fault zone or of a zone of passage: and considering both the facts of distribution referred to above and the results of interpreting the statements as to the distribution of the crystalline and metamorphic rocks contained in the papers on Orissa in Vol. 1 of the *Memoirs*, Dr. Fermor deduces that the boundary between the Dharwar-nongarnet-gneiss facies and the khondalite-garnet-gneiss facies must run roughly westwards from the coast, through the break in the coastal hill ranges occupied by the Brahmani river, through the Talcher coalfield, across the Mahanadi river between Sambalpur and Sonpur, and thence to the north of Borasambar.

Singhbhum.

59. As the result of his visits to Singhbhum this year and in the past Dr. Fermor is able to formulate certain conclusions concerning the geology of this interesting district, and the sequence of ore deposition therein. Broadly speaking the district is occupied by a wide spread of

Dharwar rocks with various igneous intrusions, of which the chief are the granite of Central Singhbhum and the Dalma Trap and epidiorite dykes, with subordinate ultrabasic intrusions in the Kolhan (see p. 10). Still speaking broadly the Dharwars have suffered a much higher degree of metamorphism in Dhalbhum at the eastern end of the district than in the Kolhan at the western end. Slates have become phyllites and schists, and quartzites with recognisable detrital grains have become vitreous quartzites. Interbanded with the Dharwars of Dhalbhum are numerous potstones, but no chromite has been found.

60. It seems a fair hypothesis to regard the Dhalbhum potstones as the representatives of the Kolhan peridotites, serpentines, and talc-schists, in which a greater degree of metamorphism has led to the complete conversion of the magnesian rocks to talc; no detailed mapping of the Dhalbhum potstones has been attempted, but they appear to occur in smaller masses than the Kolhan magnesian rocks. A smaller thickness would also have aided the more complete metamorphism.

61. With the correlation of the Dhalbhum potstones with the Kolhan magnesian rocks, the parallelism of Dhalbhum and the Kolhan seems complete. The facts as to the order of the various intrusions are regarded by Dr. Fermor as conclusive, and the sequence of events in Archæan times is believed to have been :—

(1) deposition of clays, sands, and limestones (and hematite deposits): extent of metamorphism prior to 2 unknown;
(2) intrusion of ultrabasic laccolites and sills;
(3) last period of severe earth movement, more intense in Dhalbhum than in the Kolhan;
(4) intrusions of granite (sometimes streaky);
(5) intrusions of dolerite, since altered to epidiorite.

Associated with the phyllites and schists of Dhalbhum are also some hornblende-schists. These must represent an earlier set of basic eruptions prior to the granites. Their age relative to the ultrabasic rocks, and whether lavas (basalts) contemporaneous with the sediments, or sills (dolerites) intrusive therein, is at present undetermined.

62. With reference to the sequence of mineralisation in Singhbhum Dr. Fermor considers that the iron of the hematites was probably deposited contemporaneously with the Dharwar sediments,

but the extent to which this iron has suffered subsequent rearrangement is at present unknown; the chromite was introduced with the ultrabasic rocks, and the wolfram, apatite-magnetite, and chalcopyrite, were probably introduced into the Dharwars from the granitic magma in the order mentioned. According to Maclaren the deposition of the gold was connected with the dolerite magma, but there seems to be no reason why the introduction of the gold also should not be due to the granitic intrusions.

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THE POTASH SALTS OF THE PUNJAB SALT RANGE AND KOHAT. BY MURRAY STUART, D.SC., *Assistant Superintendent, Geological Survey of India.* (With Plates 1 to 8).

I.—INTRODUCTORY.

THE re-examination of part of the salt deposits of the Punjab Salt Range and Kohat, described below, was undertaken to ascertain as far as possible what amounts of potash[1] occur in the salt beds, and their economic value. The investigation was begun in December 1915 and extended over the two field-seasons 1915-16 and 1916-17. The deposits had been examined by A. B. Wynne in the early seventies, but they had not been examined especially from the point of view of the potash salts, although the presence of potash in places was detected by him.

Comparatively recently the section opened up by the Mayo salt mine at Khewra in the Punjab was examined in detail by Dr. W. A. K. Christie for the existence of potash seams, and potash was detected by him also in the Nurpur mine, but beyond that no systematic work had been done on potash in the area.

Although the examination of the salt deposits was incidental to the potash investigation the former are described below with details of their peculiarities and nature, as far as they are known, and the potash deposits fall naturally into this description in their proper place, since they are part of the great salt formation as a whole. In the present note I deal only with the observed facts as to the distribution of the salt and with the economic aspect of the included potash deposits, while in a subsequent paper I propose to suggest a new interpretation of those facts and a new theory regarding the salt and gypsum formations.

The area examined (*infra*, Pl. 25) comprises most of the exposures in the Punjab Salt Range between the Nilawan ravine in the Jhelum district and Kalabagh on the Indus; thence the salt exposures

[1] Throughout this report the word potash means any of the naturally occurring potassium compounds, and where the compound K_2O is referred to it is called potassium oxide to avoid confusion.

were followed up through the Lun Wan pass to Nandrakka in Kohat, and from there westwards along the range through Malgin to Bahadur Khel on the Waziristan frontier, a total distance of over 200 miles. In addition to the above, isolated exposures at Banda Daud Shah and Jatta Ismail Khel in Kohat were also examined.

I am greatly indebted to the Commissioner and officers of the Northern India Salt Revenue Department for the assistance they gave me throughout my investigation, and especially to Mr. F. Reid, Assistant Commissioner of Mines at Khewra, whose knowledge of the salt beds and the various mines, saved me both time and labour, and helped very considerably to the results I have obtained.

I do not propose here to give a complete list of previous observers. The salt deposits have been thoroughly examined by Wynne and Warth, and the results of their work together with a bibliography is published in the *Memoirs* of the Geological Survey of India, Vols. XI, pt. 2, and XIV. C. S. Middlemiss did further work on the salt marl and published his views in the *Records* of the Geological Survey, Vol. XXIV, page 19. Finally, recently, Dr. Christie thoroughly examined the salt deposits of the Mayo mine at Khewra and also the Nurpur mine, and published his results in the *Records*, Vol. XLIV, pt. 4.

These four publications incorporate everything having any bearing on the economic question that had been done up to the date of their publication, and consequently are all that I need mention here.

The Punjab salt is red or brown in colour and occasionally grey; it is massive, and sometimes coarsely crystalline. The Kohat salt is grey, and generally strikingly schistose (see Plate 1); red salt is exceedingly rare in Kohat, but is not entirely absent as stated by Wynne and Warth.

The Kohat District. The rocks of the Kohat district are classified by Wynne in their natural order of superposition as follows:—

(6) Upper and Middle Tertiary sandstones, etc.
(5) Lower Tertiary sandstones, etc., or Murree beds.
(4) Nummulitic limestone.
(3) Red clay zone.
(2) Gypsum.
(1) Rock-salt.

The Nummulitic limestone and the red clay zone both contain nummulites, and are classified by him as Eocene, a classification with which I am entirely in accord. The underlying gypsum and rock-salt are classified by him as probably Eocene also, a deduction for which I have failed to find support.

The rock-salt.

The salt is described by Wynne, but, as my observations differ materially from his description, I will give them first, and will then point out wherein they differ from his description. The rock-salt of the Kohat area is a schist. It frequently cleaves easily along the planes of schistosity, and in the west of the district, as for instance at Bahadur Khel and Karak, it is sufficiently fissile to be quarried by simply splitting into slabs by means of iron wedges held between the quarryman's toes and tapped with round stones about six inches in diameter. Plate 1, fig. 1 shows a photograph, natural size, of Bahadur Khel salt, and illustrates its schistose character. Plate 1, fig. 2 represents a salt quarry at Bahadur Khel, and shows the steep angle at which the planes of schistosity dip towards the north, and the iron wedges, rounded stone, and freshly fractured slabs of salt, illustrating the method of working described above. The foliation of the salt in the Bahadur Khel salt-field will be discussed in detail below. In the east of the district the cleavage of the salt is less apparent but its schistose nature is still evident, even at Malgin and Jatta, where the salt is blasted out instead of being split along planes of schistosity. In other words the schistosity is greatest in the west of the district and least in the east, but it is still perceptible even in the east.

The salt possesses a characteristic whitish or grey colour throughout the district. Red salt does occur, but I have only found it in two places, in the clays to the west of the middle of the eastern salt hill at Bahadur Khel (see sketch plan, Plate 8), where it is obviously recrystallised, and in bands in the dark grey salt of Nandrakka in the extreme east of the Kohat district. The Nandrakka outcrop is of special interest because it is a distinct link between the Punjab and the Kohat salt, and shows not only both red and grey salt, but also chemical characters intermediate between the two types. Earthy impurities are commonest in the western part of the district, where the largest exposures of salt occur; they consist of bands of bluish-grey clay, generally discontinuous, and isolated fragments of the same clay scattered through the schistose salt as constituent

components of the rock. When the salt weathers these fragments of clay are left on the surface of the salt as projecting particles, and show up the foliation bands in a most marked manner. Plate 2 shows a photograph taken on Bahadur Khel salt-field illustrating this—the hummocks of salt in the middle distance are about four feet high—and it will be seen that the foliation of the salt is strikingly delineated by the clayey particles left projecting owing to the fairly rapid solution of the salt under the action of the usual weathering agents. The direction of foliation of the salt at Bahadur Khel does not correspond with the run or arrangement of the overlying gypsum formation, and is frequently at right angles to it. The sketch-plan of the Bahadur Khel salt-field, Plate 8, shows this well. The foliation planes were followed out and mapped wherever well seen, and their arrangement is shown by the broken lines on the sketch map. It will be seen that there is no apparent connection between them and the overlying gypsum and Eocene formations, neither of which follow the run of the foliation planes exhibited by the salt.

The field was extensively tested for the presence of potash but none was detected. This may mean either that no potash was present in the original salt from which the schist was formed, or that, being more soluble than rock-salt, any potash that may have originally been present, has been removed in solution. In either case the Bahadur Khel salt does not offer any encouragement to further search for potash.

Kark and Guruza.—The salt here is exactly like that of Bahadur Khel and is worked by splitting it along its foliation planes. No trace of potash was detected.

Intervening outcrops between Bahadur Khel and Malgin.—The various outcrops intervening between Guruza and Bahadur Khel and Malgin were all examined, but no trace of potash was detected in any of them. The salt is of the usual grey colour in all of them and is distinctly schistose, although the cleavage is not so marked as at Bahadur Khel and Karak.

Malgin.—The salt is grey and shows less tendency to cleave along the planes of schistosity than is the case in the west of the district. It is worked by blasting; nevertheless, here also, distinct schistosity can be distinguished, especially on weathered surfaces of salt.

Jatta.—Here again the salt is less markedly schistose, but nevertheless distinctly a schist.

Nandrakka.—The salt here occurs in two solution craters. The underlying salt has been removed in solution and the overlying gypsum has fallen in, leaving a deep crater-like hole, into which streams flow in the wet weather and find their way through dissolved-out channels in the salt to the Teri Tawi to the north. Salt is exposed in vertical cliffs in the sides of these craters in two places at the Nandrakka post and also near the Eja post.

The salt is blackish-grey with bituminous matter incorporated in its upper layers, and also in the overlying gypsum. Irregular streaky bands of pink salt occur in the grey salt in both exposures immediately east of the Nandrakka guard-post. Also numerous stalactites of salt are formed in the salt caves by percolating water, and the water dripping from these was in numerous instances found to give a distinct reaction for both potassium and magnesium. I do not suggest that potassium is present in quantities of commercial importance, but the interest of the observation lies in the fact that this exposure, which is intermediate in position between Kohat and the Punjab contains both grey and red salt and also traces of potassium and magnesium, which are strikingly absent throughout all the Kohat exposures investigated. The next exposure of salt, in the Lun Wan pass, approximately 20 miles to the south, near Kacho, belongs to the Punjab type. Consequently the Nandrakka exposures are intermediate in type; they are a distinct link between the two salt areas and of themselves give rise to the very strong presumption that the two salt deposits are parts of one great salt formation and are not distinct and unconnected formations.

The Punjab salt area.

As I have already pointed out, the Punjab salt is red and occasionally grey, and generally contains salts of magnesium and potassium. Its usual position is below the Purple Sandstone of the Salt Range, which underlies the Obolus Shales of undoubted Cambrian age. Occasionally it is overlain by Nummulitic limestone, as at Vasnal in the Jhelum district, or by Tertiary sandstones and clays, as at Kalabagh. But in every case, just as in the Kohat area, it is the lowest formation seen, and nothing has ever been found definitely underlying it.

The salt does not occur in regular stratified beds, but as has been noticed also by Wynne and Christie, frequently occurs in lenticular and irregular bands; these possess a foliated character although on a scale much larger than is usually understood by that

term. It in fact appears to be a foliated deposit, but whereas in Kohat the foliation is on such a fine scale that the rock can be called a schist, in the Punjab the foliation is on such a large scale that the individual foliated bands are feet, and sometimes yards, across.

This first became evident when I was investigating the Nurpur mine. On tracing out the potash seams in detail there it became at once clear that they are not only discontinuous, but thicken and thin abruptly along their length. A glance at the plan of the seams investigated in the Nurpur mine will make this evident (Plate 5). The western seam ends abruptly just to the south of the point at which it was tested by Dr. Christie,[1] and its eastern boundary follows a very curved course. The eastern seam thickens and thins in an abrupt and extraordinary manner along its length, varying, for instance, from a thickness of a few inches, at a distance of twenty-five feet from the southern end of the drift, to more than thirty times that thickness fifteen feet further north. The curves of the eastern boundary of the western potash band do not agree with the curves in the western boundary of the eastern band and obviously neither of them is an ordinary stratified bed bounded by planes of stratification. Equally obviously the salt and salt marl bands occurring between the two potash bands cannot exhibit planes of stratification in the ordinary sense of the words since they must thicken and thin in agreement with the boundaries of the potash bands. The salt bands were not examined in detail, but the thickening and thinning of some of the marl bands in them is abundantly evident.

An examination of the Mayo salt mine at Khewra, in order to ascertain if the dip of the beds changed in the north-east corner of the mine, showed that here also the banding of the salt was not due to stratification.[2]

II.—POTASH IN THE SALT DEPOSITS.

During the investigation for potash salts the whole of the Nilawan ravine was examined and every outcrop tested. The Nurpur mine was examined in detail as was also the Warcha mine. Khewra had already been examined by Dr. Christie, but as most of the potash salts there had already been worked out with the salt from the

[1] *Rec., Geol. Sur. Ind.*, XLIV, 247.
[2] This will be dealt with further in a subsequent paper.

chambers and what was left remained chiefly in the pillars, the investigation was largely of scientific interest only, while I understand that owing to the present great demand for salt it is considered inadvisable to attempt the production of potash at Khewra, unless of course some hitherto unsuspected thick band comes to light—an event which I regard as extremely unlikely.

After Warcha, Kalabagh was inspected and from there the investigation was carried on through the Lun Wan pass into Kohat and thence westwards to the Waziristan frontier. Potash was detected and mapped in the Nurpur mine, and in the Warcha mine. Traces of it were detected at Kalabagh and at Nandrakka in Kohat, but in each of these two latter cases no seam of potash salt was found, its presence being merely detected in dripping water, or in the water lying in some of the quarries.

The method of testing adopted was the perchloric acid method. A measured quantity of pulverised material from the band to be tested was dissolved in a fixed quantity of water and then treated with perchloric acid, any potash present being brought down as a white precipitate. By using graduated test tubes the volume of precipitate obtained could be measured and from that a roughly approximate idea gained of the percentage of potassium oxide present. The quantity of pulverised material taken was measured in a small quartz spoon containing about one cubic centimetre. This was dissolved in 4 c.c. of distilled water and the potash then precipitated with perchloric acid. After precipitation the tube was allowed to stand for exactly five minutes—to allow the precipitate to settle—and then the volume of precipitate obtained was read off in cubic centimetres.

From actual experiments the following results were obtained :

Precipitate obtained in cubic centimetres.	Percentage of potassium oxide present in material being tested.
0·2	5 per cent.
0·4	7 ,,
0·6	9 ,,
0·8	11 ,,
1·0	13 ,,
1·2	15 ,,
1·4	17½ ,,
1·6	20 ,,
2·0	23 ,,
2·5	27½ ,,
3·0	32 ,,
4·0	43 ,,

These figures are more accurate in the lower quantities than in the higher as experimental error is greater in more highly concentrated solutions. They are in any case only approximately quantitative.

In order to keep the quantities correct in the tests, the method adopted was to take a double quantity of material and dissolve it in 8 c.c. of water; this was then filtered through a dry filter paper and exactly 4 c.c. of filtrate taken. By this means one is sure of obtaining the full 4 c.c., and the degree of concentration of the solution is unaltered.

As regards the taking of material, potash seems to be generally exceedingly soluble, and much more deliquescent than salt, consequently it would not be satisfactory to test the surface of a salt outcrop if it showed the least signs of weathering. I came to the conclusion, however, that the material six inches inside perfectly solid fresh salt was unaffected by weathering, and that therefore material tested from such a depth was to be relied upon. I consulted Mr. F. D. Reid, Assistant Commissioner at Khewra on this point and he agreed with me. Confirmation also seems to be given by the one test in the Nilawan ravine giving a potassium reaction, where the potassium-bearing material was found in the very face—clean and unweathered, it is true—of the outcrop, where it had been exposed to the rain and air: the effect of the rain being apparently simply to remove a film off the surface by solution and leave the undissolved material unaffected.

In cases, where weathering or differential solution had taken place or where there was an efflorescence on the face of the outcrop, the outcrop was cut into until hard fresh material was obtained, and material was then taken from a depth of six inches by drilling into the face with a jumper.

The actual taking of samples, and cutting into the salt, as well as the work in the mines, was done by a number of experienced miners kindly lent me by the Salt Department. In testing an outcrop a sample was taken from every band of salt, and, where the bands were more than a foot in thickness, at intervals of a foot, except in a few cases where the bands of salt were very thick and obviously of uniform character and purity, when tests were taken only every two feet.

While it is possible, therefore, that insignificant pockets of potash may have escaped unnoticed, nothing of any commercial or economic value can have done so.

In Kohat, at Bahadur Khel, a cut was made right across the salt and all the material from this was tested, so that there none was missed.

The Nilawan Ravine.

The Nilawan ravine occupies the centre of a steep, faulted anticline running in a general north and south direction. The prevailing dip of the rocks of the Salt Range in the neighbourhood is N.N.W., but the Nilawan ravine anticline seems to have been a subsidiary sharp pucker in the rocks due to east and west compression. The fault seems generally to occupy the centre of the anticline, and is probably very largely the cause of the ravine.

Generally the anticline is steep and narrow, and the salt marl only occurs at the bottom of one or both sides; but in the neighbourhood of the Nurpur mine the anticline seems to have domed up, and a much greater thickness of salt-bearing rocks is seen. In fact the salt seams opened up by the mine are probably the lowest exposed in the ravine.

The following is a list of the outcrops tested in the Nilawan Ravine :—

Outcrop facing north under guard-post 12.

Every seam tested—20 tests—result *nil.*

Southern outcrop under guard-post 12.

Tested every two feet—41 tests—result *nil.*

Outcrop under guard-post 11.

30 tests—potash detected in uppermost band (gave 0·1 c.c precipitate). Exhaustive tests proved, however, that this was merely an isolated occurrence, and the salt around the spot. and also behind it, gave no reaction whatsoever. Practically all the potash was removed in the first material taken for testing purposes. The outcrop was cut into to a depth of ten feet but there was no recurrence of potash. Everywhere else the tests in the outcrop gave no result.

Outcrop at guard-post 11 on east side of stream.

Tested every seam—46 tests—result *nil.*

Outcrop in west bank of stream, south of guard-post 11.

Tested every seam—15 tests—result *nil.*

Outcrop N.W. of guard-post 10, east of ravine in side stream.

Tested in every impure band and where the bands were thick at intervals of 18 inches—25 tests—result *nil.*

Western outcrop opposite guard-post 10.

Tested every band of any thickness and, where the bands are thick, at intervals of 18 inches—51 tests—result *nil.*

Eastern outcrop south of guard-post 10 in right bank of stream.

Tested every band of any thickness and, where the bands are thick, at intervals of 18 inches—61 tests—result *nil.*

Small cleared outcrop 300 yards S. of guard-post 10 and east of 9.

4 tests—result *nil.*

Outcrop 100 yards S. 55° W. of guard-post 9 in west bank of small stream.

Tested every two feet—46 tests—result *nil.*

Outcrop east of, and opposite, guard-post 9 in left bank of stream.

Tested every foot—27 tests—result *nil.*

Old mine at guard-post 9.

This is unsafe to work in owing to the state of the roof. It was examined as much as possible—result *nil.*

Outcrop between present mine and guard-post 9 in right bank of stream.

Tested every foot—8 tests—result *nil.*

First outcrop west of present mine in same bank in Bhal ravine.

Tested every foot—6 tests—result *nil.*

Second outcrop west of present mine in same bank in Bhal ravine.

Tested every foot—7 tests—result *nil.*

Third outcrop, west of present mine in same bank in Bhal ravine.

Tested at approximately one foot intervals—4 tests—result *nil.*

Fourth outcrop, west of present mine in same bank in Bhal ravine.

Tested at one foot intervals—9 tests—result *nil.*

Outcrop (exposed by me) east of guard-post 7 in right bank.

Tested every seam—24 tests—result *nil.*

Outcrop opposite guard-post 7.

Tested every seam—57 tests—result *nil.*

Two small outcrops facing north in right bank of stream just below mine.

Tested every salt band—24 tests—result *nil.*

Outcrop in small stream in left bank S.S.E. of guard-post 13.

Tested every foot—15 tests—result *nil.*

Outcrop N.N.E. of guard-post 14 in left bank.

Tested every foot—17 tests—result *nil.*

Outcrop north of guard-post 14, facing north in left bank.

Tested in every seam—34 tests—result *nil.*

Bottom outcrops opposite guard-post 14.

Tested in every seam—57 tests—result *nil.*

Outcrops in enclosed ravine just no th of above.

4 tests—result *nil.*

Northern end of main outcrop opposite guard-post 14.

Tested every foot—21 tests—result *nil.*

Middle of main outcrop opposite guard-post 14.

Tested every two feet—26 tests—result *nil.*

Southern end of main outcrop opposite guard-post 14.

Tested every foot—26 tests—result *nil.*

Outcrop in left bank at stepping stones between guard-posts 14 and 15.

Tested every seam—27 tests—result *nil.*

Outcrop under guard-post 15.

Tested every seam—35 tests—result *nil.*

Northern outcrop under guard-post 16.

Tested every seam—69 tests—result *nil.*

Outcrop at top of bank under guard-post 16.

Tested every seam—17 tests—result *nil.*

Second outcrop from north under guard-post 16.

Tested every seam—89 tests—result *nil.*

Main portion under guard-post 16.

Tested every seam—95 tests—result *nil.*

Outcrop opposite guard-post 17.

Tested every seam —117 tests—result *nil.*

Two outcrops under guard-post 18.

Tested every seam—45 tests—result *nil.*

Outcrops in bluff opposite guard-post 19.

Tested every seam—110 tests—result *nil.*

Outcrops south-west of guard-post 20, facing north.

Tested every seam—53 tests—result *nil.*

Small outcrop west of above, beside stream.

4 tests—result *nil.*

Outcrop south of guard-post 20, facing south.

Tested every seam—19 tests—result *nil.*

Outcrop south of guard-post 20, facing west.

Tested every seam—46 tests—result *nil.*

Outcrop under guard-post 21.

Tested every seam—30 tests—result *nil.*

The Nurpur Salt Mine.

There are two potash seams in this mine, in the east and west walls of what is known as the "potash drift." I have already

East Wall.

DISTANCE OF TEST FROM SOUTHERN END OF POTASH DRIFT.	APPROXIMATE PERCENTAGE OF POTASH. Depth into wall.												
	6"	1'	1' 6"	2'	2' 6"	3'	3' 6"	4'	4' 6"	5'	5' 6"	6'	6' 6"
10' .	*nil.*	9	5	8	2	2	..	..	..	..	..	..	..
20' .	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	..	..	..	..	..	..	..
30'	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	..	..	..	..	..	..	..
40' .	9	9	10	17	17	15	13	13	25	13	..	..	..
50' .	5	6	13	13	8	15	32	15	17	18	15	13	2
60' .	16	16	11	5	21	21	18	..	..	..	..	..	..
70' .	17	9	5	marly *nil*	*nil.*	*nil.*	*nil.*	..	..	..	..	..	..
80' .	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	..	..	..	..	..	..	..
90' .	*nil.*	*nil.*	*nil.*	*ni*	*nil.*	*nil.*	..	..	..	..	..	..	..

West Wall.

Distance of test from southern end of Potash drift.	Approximate Percentage of Potash. Depth into wall.																			
	6″	1′	1′ 6″	2′	2′ 6	3′	3′ 6″	4′	4′ 6″	5′	5′ 6″	6′	6′ 6″	7′	7′ 6″	8′	8′ 6″	9′	9′ 6″	10′
10′ . .	13	13	13	11	12	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..
20′ .	7	*nil.*	7	11	12	13	13	10	..	..	..	..	..	..	..	..	..	..	..	..
30′ . .	*nil.*	*nil.*	*nil.*	*nil.*	trace	9	11	..	..	..	..	..	..	..	..	..	..	..	..	..
40′ . .	6	*nil.*	6	7	12	16	18	..	..	..	..	..	..	..	..	..	..	..	..	..
50′ .	*nil.*	*nil.*	6	7	9	7	7	..	..	..	..	..	..	..	..	..	..	..	..	..
60′ . .	*nil.*	*nil.*	*nil.*	trace	13	13	..	..	..	..	..	..	..	..	..	..	..	..	..	..
70′ . .	*nil.*	*nil.*	*nil.*	trace	8	7	11	..	..	..	..	..	..	..	..	..	..	..	..	..
80′ . .	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	trace	13	8	..	..	..	..	..	..	..	..	..	..	..
90′	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	*nil.*	trace	*nil*	9	*nil*	13	13	13	[illegible]	11	17	32	15	21

West Wall—continued

Distance of test from southern end of Potash drift.	Approximate Percentage of Potash.																			
	Depth into wall.																			
	10′ 6″	11′	11′ 6″	12′	12′ 6″	13′	13′ 6″	14′	14′ 6″	15′	15′ 6″	16′	16′ 6″	17′	17′ 6″	18′	18′ 6″	19′	19′ 6″	20′
10′ . .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
20′ . .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
30′ . .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
40′ . .	..	..	.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
50′ . .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
60′ . .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
70′ . .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
80′	.	..	..	..	..	..	..	..	..	..	..	.	..	..	..	..	..	..	..	..
90′ . .	13	14	13	13	14	11	21	12	13	15	12	14	16	15	11	37	32	trace	2	nil.

referred to the way in which they thicken and thin and even end abruptly: phenomena which I ascribe to metamorphism that has occurred in the salt deposits. Not only do the potash bands vary abruptly in thickness and direction, but they vary throughout their length in the percentage of potassium present in them. A glance at the above figures will make this evident. They represent the results of tests made in the sides of the potash drift in the Nurpur mine. This drift was run with the intention of keeping in touch with, but just outside the eastern boundary of, the western potash band which had been located by Dr. Christie.

In order to test the deposit, holes were drilled into the side walls of the drift on both the east and west sides, by means of a jumper, and the material extracted was collected and tested after each six inches of progress. In this way a series of tests was made, giving the average potassium content of every six inches drilled into the walls. These drill holes were carried into the walls as far as was possible with the jumpers at my disposal and where it seemed necessary to get further in than could be done in this way, the walls were blasted out when the jumpers had been driven in as far as possible, and so further progress was made possible. These tests were made into both walls at intervals of ten feet starting from the southern end of the drift.

From these tests it will be seen that the potassium contents of the two seams, or bands, of potash are not fixed quantities for the respective seams, but vary throughout their length. For instance, it is obvious that material excavated to a depth of two feet six inches into the west wall at a distance of 10 feet from the southern end of the potash drift, would have an approximate content of 12 per cent. K_2O (corresponding to an average precipitate of 0·94 c.c.), while potash excavated from a similar depth into the band at a distance of 50 feet from the southern end of the drift—the potash band is separated from the drift by a thickness of one foot of salt at this point—would only have an average content of 6 per cent. K_2O (corresponding to an average precipitate of 0·3 c.c.).

This is of great importance in any statement made regarding the analysis of samples taken from the potash seam. In each case the results of the analysis are merely indicative of the average potassium content of the band at a particular point, the point where the sample was taken. The potassium content may be, and almost certainly is, very different a short distance away. For instance, in the particular

cases mentioned above there is a variation of something like 100 per cent. in the potassium content of the potash band in a length of 40 feet.

A series of investigations was also carried out, on material taken from the southern face of the western potash band, by the Director of Industries, United Provinces, the results of which were kindly communicated to me by the Commissioner, Northern India Salt Revenue, and permission to use them in this report was given me by the Director of Industries.

The first results were obtained by the platinic chloride and the mixed chlorides methods of analysis for potassium, and gave a result of 22·6 per cent. potassium chloride, KCl, which is equivalent to approximately 14·3 per cent K_2O[1]. This agrees very closely with the rougher analysis done in the ordinary course of my investigations, 1·0 c.c. of precipitate being obtained by me.

The Director of Industries, United Provinces, further suggested "the composition corresponds very closely to that of kainite." This agrees with my own conclusions.

At the risk of being thought to repeat myself I would again point out that these figures and conclusions merely refer to the potash band at the southern end of the drift and not to any other point in it.

Mining the potash.

The above brings me to the precautions necessary in the mining of potash at Nurpur. What has to be avoided is the mixing of salt with potash either when excavating the material or when bringing it out of the mine. Crude potash has a definite value and that value is diminished if the potash contains an admixture of salt. It may, I think, be taken that the value does not decrease in proportion to the percentage of salt included, but that there is a very rapid decrease in value as the salt increases. That being so it is obviously necessary to prevent salt becoming mixed with the potash while extracting the latter in the mine.

[1] The detailed analysis obtained was :—

	Per cent.
"K	11·8
Mg	9·8
SO_4	46·3
Cl	17·9
	85·8

The rest being presumably sodium, water, and traces of insoluble matter."

Since the bands of potash do not behave as normal stratified deposits their boundaries can be determined only by actual experiments. Appearance is of no use at all; potash can sometimes be detected in this way, but confirmatory tests show that one is misled as often as one is correct in identifications made thus, and frequently there is no visible difference whatever between the material just inside the boundary of a potash band and the adjoining material just outside it.

Taste is a fairly reliable test once; after that one's palate is so affected by the bitter taste of the potash compounds that it is impossible for about half an hour to distinguish between potash and salt. Consequently the only test that remains is the chemical one. Chemical tests should be made continuously, therefore, and the position of the boundaries of a band indicated to the miners, so that they may extract only the potash and leave the salt; and as the bands vary so greatly in thickness, these determinations will have to be made every foot or so along the run of the band.

The best plan will probably be to have the drift a little wider than the potash band, and to mark out the two boundaries of the band on the working face; the miners should then cut into the salt, or salt marl, immediately outside these boundaries to a depth of a foot, and blast out the potash between their cuts. After this, the position of the boundaries should be verified or corrected, and the same procedure repeated; and so on. It is necessary that the edges or boundaries should be cut, and not blasted, since blasting will give an irregular edge and bring in a certain amount of salt. Miners find the potash hard to cut with picks, but, in the procedure suggested it will be noticed that they need not cut into the potash, but into the salt or marl immediately outside the boundaries of the bands.

As progress proceeds it will be necessary to keep the sides of the drift wider than the potash band so as to allow for the ready following of any widening of the band, but there should be no difficulty in keeping the potash extracted from between the two cuts separate from the material removed from outside them.

The Warcha Mine.

Potash was found to occur in three chambers in the Warcha salt mine. It occurs in the working faces of the disused portions of chambers 2 and 3, and also in the middle of the old exploration

tunnel in chamber 4 (*see* plan and sections of part of Warcha mine, Plates 6 and 7).

Its occurrence is peculiar. It was encountered unexpectedly while the chambers were being worked for salt, and since its presence made the salt unpalatable, work was stopped in these particular chambers (2 and 3).

In view of the experience gained at Nurpur, it would appear that the end of a potash band has been reached in each case, and that that band is starting abruptly, just as the western band at Nurpur does. How far it runs in a forward direction it is impossible to say, but some information is given by the new exploratory drift run by the Salt Department at my request from the bottom of chamber No. 4. All the three occurrences first mentioned are sufficiently nearly on the same plane for them to belong to one and the same potash band. The new exploratory drift at the bottom of chamber No. 4 cuts through potash also on this plane, so that the inference that they are one and the same seam is justified. The potash in the new exploratory tunnel is only a trace, however, and shows that under the lower portion of chamber 4 the potash, rather than thickening, thins away to almost nothing. Another small seam of potash about eight inches in thickness and yielding about 12 per cent. of K_2O occurs in this new tunnel, at a higher horizon than that just mentioned.

The structure of the salt deposits opened up by the mine is interesting. More or less through the centre of the working chambers of the present mine there runs a band of marl and magnesium salts which is a very characteristic feature of the mine. We may in fact call it the 'main marl band' of the mine. About 50-55 feet below this in the section of the salt, is a peculiar red salt-marl breccia about two feet thick. It seems to consist of a salt-marl matrix with brecciated lumps of marl containing less salt than the matrix. It is quite characteristic, and, once seen, cannot be mistaken; throughout the mine it is parallel to the foliation of the salt, forming a valuable, and easily recognizable, horizon. It is seen in both the exploratory tunnels in chamber 4, and also in the tunnel just to the north of the disused chamber in No. 2, and also in the new lower tunnel now being driven to open up the lower workings of the mine. About 20 feet below this Red Marl breccia is the potash in chamber No. 2 and in the exploratory drifts in No. 4.

About 20 feet below the potash horizon in the exploratory drifts in No. 4 is the line of an apparent overthrust, marked by shattered and brecciated beds containing clay, gypsum, red and grey salt, in shattered lumps[1]; beneath this is grey salt with grey clay, not regularly banded as the red salt is above the line of the overthrust, but much contorted, and in its upper portions overfolded towards the south; it is best seen in the lower exploratory tunnel in No. 4. It indicates that the overthrust has come from the north; and the plane of faulting seems to be approximately parallel to the general direction of foliation of the overlying red salt.

The strike of the foliation of the salt is not always uniform, however. The main marl band is found to rise when traced along the low-level tunnel through chambers 3, 2 and 1 and then to dip down again under the floor of the old mine, until at the extreme north-east corner of the old mine I estimate that it is about 24 feet below the floor of the mine. This would bring it across the new lower tunnel just east of survey peg 81, and one finds, 23 feet along the tunnel in a westerly direction measured from peg 80, a marl band resembling it so closely that there is little doubt as to the identity of the two. 43 feet along the tunnel in an easterly direction from peg 80 is the Red Marl breccia, in its right place, about 50 feet in section below the main marl band, and immediately below this is the overthrust showing the same characteristics that it did in the bottom of the lower exploratory tunnel in No. 4. This is followed by a bad 'wash-out,' and for some distance eastwards in the tunnel only earth débris and rock fragments are seen, and then comes contorted grey salt with grey clay and brecciated gypsum fragments comparable with that seen below the overthrust in the lower exploratory drift in No. 4.

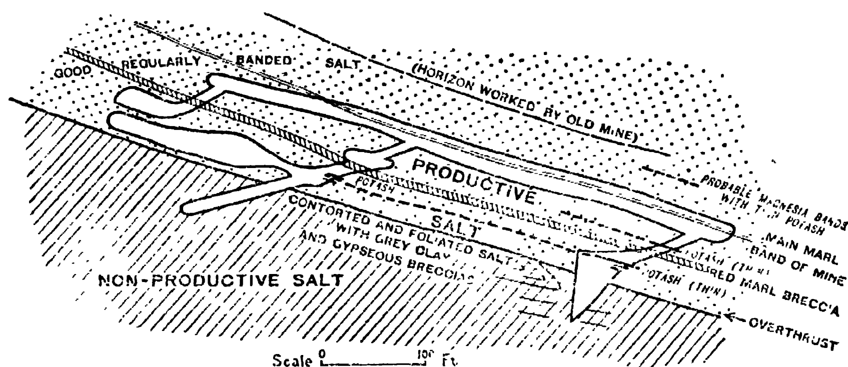
The potash seam of chambers 2, 3 and 4, seems to be cut out by the overthrust here, and consequently is not seen; if the overthrust were not there, its position would be about the middle of the section occupied by the wash-out. The new lower tunnel gives us no assistance in the matter of this potash seam therefore.

There is evidence of more potash above the level opened up by the mine. Water dripping in the disused chamber No. 2 reacts for potash. Also water dripping in the high-level tunnel at the corner of chamber 2, and water dripping in the Brattice tunnel near No. 2, react for potash; also water dripping from the roof of No. 0. This

[1] This is discussed more fully in the following paper.

may be the same as a thin seam of combined magnesium and potassium sulphates that crosses the new lower tunnel at survey peg 82. There is only a trace of potash in it there, but quite sufficient to be collected by percolating water. It is at a higher level in the section of the salt than the main marl band and therefore, if continuous, would be somewhere above the roof of the existing mine.

The following sketch section of chamber No. 4 shows the arrangement of the various bands I have been discussing and of the overthrust :—



The potash so far exposed in the mine is not promising. The following are the results of the tests made :—

Chamber No. 2.

Tests were made every six inches vertically in four positions in the face with the following results (giving approximate percentage of K_2O) :—

No. of test.	Position A.	Position B.	Position C.	Position D.
	Per cent.	Per cent.	Per cent.	Per cent.
1	*nil.*	*nil.*	*nil.*	*nil.*
2	7	*nil.*	11	7
3	*nil.*	6	*nil.*	11
4	*nil.*	2	10	trace
5	*nil.*	13	trace	13
6	*nil.*	*nil.*	11	*nil.*

No. of test.	Position A.	Position B.	Position C.	Position D.
	Per cent.	Per cent.	Per cent.	Per cent.
7	*nil.*	*nil.*	trace	11
8	*nil.*	9	*nil.*	16
9	trace	6	7	8
10	trace	9	7	13
11	*nil.*	2	18	11
12	*nil.*	5	5	8
13	*nil.**	9	*nil.*	trace
14	*nil.*	9	trace	8
15	*nil.*	trace	5	5
16	*nil.*	*nil.*	5	7
17	*nil.*	trace	8	21
18	*nil.*	*nil.*	8	17
19	*nil.*	trace	21	19
20	*nil.*	*nil.*	40·5	*nil.*
21	*nil.*	trace	5	trace
22	*nil.*	*nil.*	trace	11
23	*nil.*	*nil.*	*nil.*	*nil.*
24	*nil.*	2	..	*nil.*
25	*nil.*	13	..	*nil.*
26	*nil.*	*nil.*	..	trace
27	*nil.*	*nil.*	..	..
28	*nil.*	*nil.*	..	..
29	..	*nil.*	..	..
30	..	trace	..	..

In addition to the above a small isolated mass in the south wall of the chamber gave, when tested, 40·5 per cent. K_2O.

Chamber No. 3.

Tests were taken in three positions in the face of the salt, the test holes being six inches apart, with the following result :—

No. of test.	Position A.	Position B.	Position C.
		Per cent.	Per cent.
1	*nil*	7	*nil.*
2	*nil.*	*nil.*	7
3	*nil.*	*nil.*	trace
4	*nil.*	6	8
5	trace	*nil.*	*nil.*
6	*nil.*	trace	*nil.*
7	*nil.*	6	*nil.*
8	*nil.*	trace	*nil.*
9	*nil.*	*nil.*	*nil.*

No. of test.	Position A.	Position B.	Position C.
		Per cent.	Per cent.
10	*nil.*	*nil.*	*nil.*
11	*nil.*	5	*nil.*
12	*nil.*	8	5
13	*nil.*	trace	trace
14	*nil.*	7	6
15	*nil.*	*nil.*	*nil.*
16	*nil.*	*nil.*	*nil.*
17	*nil.*	*nil.*	*nil.*
18	*nil.*	8	*nil.*
19	*nil.*	*nil.*	*nil.*
20	*nil.*	*nil.*	*nil.*
21	*nil.*	trace	*nil.*
22	*nil.*	trace	5
23	*nil.*	*nil.*	*nil*
24	*nil.*	*nil.*	*nil.*
25	*nil.*	2	*nil.*
26	*nil.*	5	*nil.*
27	..	trace	*nil.*
28	..	13	trace
29	..	10	5
30	..	13	*nil.*
31	..	8	*nil.*
32	..	trace	*nil.*
33	..	5	*nil.*
34	..	*nil.*	*nil*
35	..	11	*nil*
36	..	trace	*nil.*
37	..	*nil.*	*nil.*
38	..	*nil.*	*nil.*
39	..	*nil.*	*nil.*
40	..	*nil.*	*nil.*

Upper exploratory drift off Chamber No. 4.

20 tests across the potash band at intervals of six inches.

No. of test.	Percentage of K_2O.
1	5
2	16
3	trace.
4	12
5	10
6	8
7	8
8	*nil.*
9	trace.
10	*nil.*

No of test.	Percentage of K_2O.
11	*nil.*
12	5
13	trace
14	*nil.*
15	*nil*
16	*nil.*
17	*nil.*
18	*nil*
19	trace.
20	*nil.*

The same seam in the lower exploratory drift off No. 4 had thinned away to almost the merest string and only gave a faint reaction for potash.

Kalabagh.

The salt quarries at Kalabagh were all fairly thoroughly examined. Potash was detected either in dripping water, or in water lying in the quarries, in Nos. 6, 10, 17 and 18.

As the numbers at Kalabagh are not numbers of the quarries, but are numbers assigned to certain quarrymen it is obvious that a number may take itself off to some other situation ; Plate 3 is from a plane-table plan of the Kalabagh quarries indicating those in which potash was detected.

No seam of potash was detected in any of the quarries, the only trace being shown by the percolating water.

Calcium sulphate is generally present in the salt and can be detected always in a chemical test, while magnesium compounds seem to be present only in very small quantities. I also noticed the formation of stalactites covered with a cotton-wool-like growth of sodium sulphate ; bands of grey salt also occur.

III.—ECONOMIC CONSIDERATIONS.

Potash.

In discussing the economic possibilities of potash in the salt deposits, I will deal first of all with the various localities at which it is known to occur, and then with the Salt Range as a whole.

Khewra.

Potash salts occur in the Mayo mine at Khewra. They were discovered in 1873 by H. Warth. They have recently been very thoroughly examined by Dr. Christie and described in a paper published in Vol. XLIV, of the *Records, Geological Survey of India.* He describes the deposits in detail, and gives an idea of their magnitude. It must be realized, however, that most of the exposures seen by Dr. Christie are in the pillars between the chambers, and that the potash has been excavated from the chambers, together with the salt, many years ago. It is, of course, impossible to excavate anything from the pillars, since this might endanger the stability of the mine; hence most of the exposures are only of scientific interest and represent no economic possibilities. What Dr. Christie calls the Buggy potash seam, however, appears to be thickening in a forward direction down the dip of the foliation, and it might be that if this were followed beyond the present end of the mine a workable quantity of potash would be found. Its thickest exposure, as seen by Dr. Christie, is only 0·95 metre, but as it thins out as it is traced up the rise of the foliation bands, it is quite possible that it may thicken somewhat down the dip. As Khewra is the main source of supply of salt in Northern India, and as the excavation of irregular lenticles and foliæ of potash would upset the scheme of pillars and chambers of the mine, it is a question whether it would be worth while to attempt to do anything with the potash. It might be worth while to run an exploratory drift down the dip of the band from the point described by Dr. Christie as "s" in chamber No. 30, to see whether the potash thickens to any appreciable extent.

If further prospecting is attempted at Khewra, the best course would be to put a boring down at the northern end of the Khewra glen, and so cut through a greater thickness of the salt than is opened up in the Mayo mine. A certain amount of potash will always occur as lenticles in the foliated salt of Khewra and Warcha. The evidence so far obtained indicates that these lenticles will, however, be discontinuous, and will not all lie on the same foliation plane, and a boring put down through the salt at any particular point may—and, if deep enough, almost certainly will—pass close by the end of one or more of these lenticles, or foliæ, of potash, without showing, in the core obtained, any indication of its presence. It is

unfortunate that this should be so, but it is one of the disadvantages from which the Indian deposits suffer as compared with unmetamorphosed deposits in other parts of the world.

Nurpur.

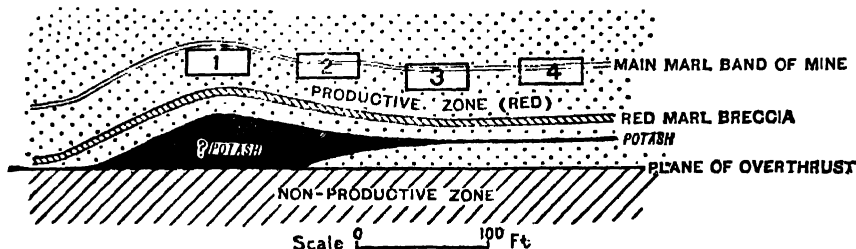
The potash bands at Nurpur have been discussed and a plan showing their position and extent is appended (Plate 4). The salt at Nurpur is more contorted and disturbed than that at Khewra, and is foliated rather than banded. The lenticles of potash are more irregular than those at Khewra, and thicken and thin, and even end, abruptly. The greatest care should be exercised in working them, and the only plan to adopt would be to follow them so long as they continue to exist. Once they end there is no reason to suppose that they will continue again further along the same foliation plane; the next potash lenticle may be on another foliation plane. Prospecting in the mine could be done by exploring in a horizontal direction towards the west beyond the most westerly point yet opened up by the mine, but there is no particular evidence to show that potash will be met with close at hand. A boring could of course be put down anywhere along the ravine, south of the mine, where the salt is less intensely folded, but owing to the fact that the Nilawan ravine lies along a faulted subsidiary anticline, and that the centre of it is a running stream, there are many other places in the Salt Range where a boring could be put down with greater advantage; the difficulty and cost of transport is another unfavourable factor at Nurpur.

Warcha.

There is one main potash seam in the mine at Warcha. It is seen in the working faces of the abandoned chambers Nos. 2 and 3 and also in the upper and lower exploratory drifts in chamber No. 4. It has indications of being of some thickness in the working faces of chambers Nos. 2 and 3, is only a few feet thick in the upper exploratory drift in chamber No. 4, and where cut by the lower drift it has thinned out down the dip of the foliation to the merest string of potash. There is another small string of potash cut by this lower drift, but it is only a few inches thick and evidently does not continue up the rise of the foliation planes. There is also a trace of potash in the new lower tunnel at peg 82, but it is a mere trace. It probably continues over the mine, for water dripping from the roof frequently shows traces of potash when tested.

As I have pointed out above (p. 45) the salt bands rise along the low-level tunnel as one passes from chambers 3 to 2 and thence to 1, and then fall away again rapidly and dip down below the floor of chamber 01. A bulge, which may be due to a thick lenticle, appears to occur under the floor of the chambers at this place, since all around it the dip and strike of the foliation planes is unchanged; and it is possible that the potash thickens here into a large augen-shaped lenticle. This is of course purely hypothetical, but I think it is sufficiently probable to merit exploration. The top of the lenticle should be 40 or 50 feet below the floor of the existing chambers; hence, if there, it could be safely excavated in chambers below those now existing; at the same time there is no reason why it should not be thirty feet or even more in thickness, but the lower portion would probably be cut off by the subsidiary overthrust which divides the red salt of Warcha—which may be called the productive zone of the mine—from the impure and grey contorted salt which underlies it,—which latter may be called the non-productive zone of the mine. Even so a considerable quantity of potash would be present. In order to determine whether this presumed potash lenticle really exists, either a direct boring might be put down or an exploratory drift might be run from chamber No. 1 at right angles to the foliation of the salt and approximately under the low-level tunnel. If it be found impracticable to run an exploratory drift so steeply, it should be run in such a way that it will intersect a line, drawn from chamber No. 1 at right angles to the foliation, at a point 50 or 60 feet from that chamber.

The following diagram shows a hypothetical section along the line of the low-level tunnel :—



As in the case of Khewra, a boring might also with advantage be put down through the salt deposits at the northern end of the

Warcha glen, close to the northern guard-post, and on the western side of the glen. This would pass through a considerable thickness of salt not seen in the mine. Nothing can be deduced, in this connection, from the dip of the foliation planes, but investigation would be interesting and should yield lenticles of potash. The same disadvantage exists here as at Khewra, and indeed throughout the Salt Range, that the lenticles of potash are discontinuous and many may be missed owing to the boring passing just outside their limits.

Warcha is now connected with Gunjyal railway station by a broad-gauge siding, hence the cost of transport would be low.

Kalabagh.

No seams of potash were found at Kalabagh, though potash was detected in both dripping water and in water lying in the quarries, in Nos. 6, 10, 17 and 18 (see Pl. 3). The salt is more contorted than at either Khewra or Warcha, and no thick seams occur. For reasons which I will give in a subsequent paper, I do not think that Kalabagh calls for any further investigation, or offers any prospect of success.

Nandrakka.

This salt is the grey variety of the Kohat zone, with a few bands of pink salt interfoliated with it. Traces of potash were detected in water dripping from the deposit, but no potash seams. I do not think the locality offers any promise or calls for any further exploration; and its inaccessible situation renders it of still less economic interest.

Kohat.

Other than at Nandrakka, no traces of potash have been detected in Kohat. From the point of view of potash, therefore, the Kohat area must be condemned.

Summary.

On the whole the evidence collected during my investigations points to the conclusion that no continuous bed of potash will be found in the Salt Range or in Kohat. The salt is a foliated rock and the potash salts occur in discontinuous lenticles and irregular foliæ. Where the foliation is of the nature of banding, bands of potash may persist for some little distance, but even then they will probably thicken and thin throughout their length. The prospects of obtaining potash in the Salt Range are not therefore promising, and it is not likely to be worked profitably except as a by-product of salt-mining.

EXPLANATION OF PLATES.

PLATE 1.—FIG. 1. Bahadur Khel salt showing schistose structure.
FIG. 2. A salt quarry at Bahadur Khel
PLATE 2.—The schistosity of Bahadur Khel salt.
PLATE 3.—Plan of salt quarries at Kalabagh.
PLATE 4.—Plan of Nurpur mine.
PLATE 5.—Plan of potash drift, Nurpur mine.
PLATE 6.—Plan of portion of Warcha salt mine.
PLATE 7.—Section of chambers in Warcha mine.
PLATE 8.—Sketch map of portion of Bahadur Khel salt-field.

SUGGESTIONS REGARDING THE ORIGIN AND HISTORY OF THE ROCK-SALT DEPOSITS OF THE PUNJAB AND KOHAT. BY MURRAY STUART, D.SC., *Assistant Superintendent, Geological Survey of India.* (With Plates 9 to 25).

I.—INTRODUCTION.

IN the preceding paper I have dealt with the general nature of the potash deposits as far as they are known, and have given details of the experimental work carried out in an investigation recently made with a view to ascertaining their economic value. During that investigation a number of facts were observed which have hitherto attracted little or no attention. The consideration of these has suggested to me a new and simple hypothesis of the history and arrangement of the salt and gypsum formations.

As pointed out in the preceding paper the area examined comprises most of the exposures in the Salt Range between the Nilawan ravine in the Jhelum district and Kalabagh on the Indus; thence the salt exposures were followed up through the Lun-Wan pass to the Nandrakka salt exposure in Kohat, and from there westwards along the range through Malgin to Bahadur Khel on the Waziristan frontier, a distance of over 200 miles. In addition to the above, isolated exposures at Banda Daud Shah and Jatta Ismail Khel in Kohat were also examined.

Since Wynne's time the salt deposits have always been the object of much speculation, and Sir Thomas Holland and many other geologists have offered suggestions attempting to link up the two great deposits of the Punjab and Kohat, joining them as one salt formation rather than considering them, as Wynne was content to leave them, two widely separated formations in point of time, the one of pre-Cambrian[1], and the other of Tertiary, age.

[1] Wynne merely classed the Punjab salt as pre-Purple Sandstone, but the discovery by Warth—subsequently confirmed by Middlemiss (*Rec. G. S. I.*, XXIV, p. 24)—of trilobites in the overlying Obolus Shales established the age of the Purple Sandstone as earliest Cambrian at least.

In the preceding paper reference has already been made to the literature on the subject of the salt and it is only necessary to add here one further reference, *viz.*, to the article on the geology of India, by Sir Thomas Holland, published in the *Imperial Gazetteer* (1907).

II.—GEOLOGY.

The salt is everywhere the lowest formation seen. Whether it is in its normal position, or not, has been the subject of much speculation. Wynne apparently came to the conclusion that it was in its normal position in the geological section in each case, in both the Punjab and Kohat and that there had been two salt-forming periods, the one pre-Cambrian, and the other early Tertiary; whereas Sir Thomas Holland suggested that the two salt sheets are parts of one extensive formation, and, taking Wynne's interpretation of the Kohat area as correct, and assuming the Kohat salt to be approximately early Tertiary in age, he suggested the existence in the Punjab of an overthrust bringing the Purple sandstone and Cambrian beds above the Salt marl, which would in that case be early Tertiary in age.[2]

The origin of the salt and Salt Marl has always been the subject of conjecture and theory. Fleming first attempted to explain it by considering it to be of an eruptive character. Subsequently he abandoned this view, and assumed that the salt deposits were originally stratified, but that they had probably undergone metamorphism from igneous influence. Warth always took it for granted that the deposits were sedimentary in character, but does not appear to have stated his reasons for holding this view. Owing to the numerous instances of lenticular arrangement in the deposits, to his frequent observance of "layers of the salt thinning out, convex above and below" and instances of anomalous contortion in certain bands of salt, Wynne hesitated to enunciate any definite opinion on this question in his memoir on the Salt Range. Christie weighs up the evidence for and against a sedimentary origin, and thinks that the observed facts may be explained by the evaporation of a saline inland lake, preferably shallow, and that the lenticular beds observed by him in the deposits were due to the fact that under such conditions "crystallization would not necessarily

[2] *Op. cit.*, I, p. 64. (1907).

proceed uniformly, but the mother liquors would accumulate in the lower basins of the region, there depositing their potassium and magnesium salts and giving rise to lenticular beds such as we find in the Buggy section of the Khewra mines."[1] This suggestion, however, does not seem to explain satisfactorily the convexity of the lenticular layers both above as well as below; it appears probable that under such conditions the upper surfaces of the lenticles could at most only be flat, and would in all probability be concave. The hypothesis, therefore, fails to explain the present observed lenticular nature of the deposits, for which some further explanation must be sought. At the same time Christie does not regard the salt deposits as wholly unaltered sedimentary strata, but expresses the view that they have experienced a certain amount of thermal metamorphism, and also that they have assumed a pasty character, under pressure, and have to a slight extent undergone some form of internal flow movement under its influence; the present banded character of the salt, however, and its lenticular arrangement, is attributed by him to original stratification.

The salt generally has a distinctly banded appearance and consists of layers of different colour and purity. Wynne describes this appearance as follows :—

"The rock-salt .. alternates with thick, dark-brownish red beds of impure saline marl, called by the natives *kallar,* and is pink, reddish, or white, rarely having grey blotches, but frequently showing numerous alternations of laminæ of small thickness, reddish and white colour and different degrees of opacity.

* * * * * *

The banded structure of the salt beds is chiefly caused by layers of different colour, the bands being most solid looking or of darkest colour about the middle and softened into a paler tint on the edge; sometimes there are alternating layers of a red earthy nature from which Epsom salt effloresces. .... the bands or layers having in some places for considerable distances vertical to their planes a general thickness of 6 to 8 inches varying to 2 feet, while for several yards across the strike in some of the larger beds no lamination at all is seen. There are also numerous irregularities of the bedding showing much lenticular arrangement of deposition .... No sign of current (ripple) mark or of well-developed oblique lamination could be found. Layers of the salt thinning out, convex above and below, were frequently seen."

A photograph of this banding effect in the salt is shown on Plate 20, which also shows the lenticular nature of some of the bands. (Seen best if Plate is viewed from a distance of several feet).

[1] *Rec. Geol. Surv. India,* XLIV, p. 259.

After careful study of the salt deposits throughout the Salt Range and up to the borders of Waziristan, I have been forced to the conclusion that the present banding in the salt is not original stratification. It frequently shows a distinctly lenticular arrangement, the individual crystals very often have a lenticular shape, corresponding almost exactly to the *augen* in an augen-gneiss, and when the salt contains a certain amount of marl the appearance of flow-structure is frequently so striking that I have been forced to the conclusion that at some time subsequent to their original deposition the deposits have been subjected to pressure, and under this, aided probably by the action of heat and the presence of water, have become sufficiently plastic to flow, and have thus acquired a flow structure very similar to that produced by movements in a nearly solidified igneous magma,—the result having been to produce a banded flow structure, which is sometimes a foliated structure consisting of lenticular bands of salt and associated minerals, and sometimes more or less regular bands similar to those occurring in a banded gneiss, but differing, in this case, in that the individual bands may be feet and even yards across.

There is an interesting confirmation of this idea, beyond the observed behaviour and frequently lenticular form of the bands of salt and allied minerals, and this is given by the existing salt marl (*kallar*) bands. These bands consist of rock-salt, with calcium sulphate, impalpable ferruginous clay, and innumerable quartz grains, of all sizes up to about 0·2 mm. and almost all highly angular in outline (*see* Christie, *op. cit.*, page 260). If a series of sediments consisting of strata of different hardness (such as a series of salt beds with occasional interbedded bands of argillaceous and arenaceous material) were subjected to dynamic metamorphism, it might be expected on theoretical grounds that the hard bands would be converted into a sort of crush-breccia. If, in addition to this, movement of the nature of flow took place, these crush-breccias would assume the form of bands in the direction of the flow, and should give, in the instance cited above, a rock corresponding to the salt-marl bands existing at the present day. This indeed would seem to be the simplest method of accounting for those bands and for the manner in which they repeatedly vary in thickness, as well as for their behaviour generally. It would also offer a satisfactory explanation of the lenticular form of some of the salt bands and

the potash bands, as well as of the anomalous occurrences observed by Wynne and Middlemiss.

In order to avoid confusion, therefore, I do not propose to refer in this paper to beds and bedding in connection with the salt deposits as they exist at the present day, but to bands and banding. or foliation planes.

Middlemiss suggested an igneous origin for the Salt Marl of the Salt Range, but this does not seem to have found much acceptance. The possible reasons are: firstly no parallel instance can be pointed to in any large salt deposit and secondly the composition of the seams, and of the minerals they contain, corresponds closely with that of undoubted salt-lake and desert deposits, such as the Stassfurt salt of Germany, the resemblance extending even to the occurrence of the peculiar bluish or indigo staining sometimes found in salt crystals at Stassfurt and attributed by S. W. Johnson to the presence of sodium subchloride, by Ochsenius to the presence of sulphur, and by Wittjen and Precht to an optical effect due to the presence of thin cavities, having parallel surfaces, with gas inclusions (*Ber. Chem. Ges.*, XVI, 1454, p. 1883). Crystals showing this bluish or indigo colour were shown me from the Mayo mine, Khewra, and I also found them at Warcha in an exploration drift which the Salt Department were excavating for me in the lower levels of the mine. So far as my own observations are concerned, I have no reason to doubt that the salt was originally deposited from an evaporating saline solution, but I am also of opinion that since their original deposition, the deposits have acquired flow structure under the influence of pressure, probably assisted also by heat and the presence of a certain amount of water.

In my earlier paper I have dealt fully with the foliated character of the Kohat salt, but I left for subsequent consideration the observation that the bluish-grey clay in the salt at Bahadur Khel contains sulphide of iron. Crystals of sulphide of iron are not rare in the blue clay, in fact in places in the Bahadur Khel salt-field they are sufficiently abundant, and decompose sufficiently rapidly under atmospheric agencies, for the particular clay bands to smell distinctly of sulphuretted hydrogen after a heavy shower of rain. A sample of clay containing no visible pyrites placed in the end of a closed tube, the other end of which was connected to an ordinary filter pump, caused the immediate darkening of a lead test paper

placed in the outer end of the tube, when the end containing the clay was gently warmed. Moreover, not only do the clay bands contain sulphide of iron, but crystals of pyrites occur in the salt itself. This was also recorded by Wynne, who writes :—" In the eastern parts of the district, besides the foreign matter previously noted, the uppermost portion of the salt . . . . is sometimes slightly pyritous . . ." Similarly at Bahadur Khel samples of salt taken by my staff were found to contain crystals of pyrites. It may therefore be said that pyrites is not confined to any particular part of the salt, or of the area, but occurs occasionally throughout the Kohat salt. The grey coloration of the Kohat salt is probably intimately connected with this presence of iron sulphide in the salt deposits. If anything occurred to convert the ferruginous matter into sulphide during the deposition of the Kohat salt, it would follow naturally that the deposits would be coloured grey rather than red. Sulphuretted hydrogen springs or an accession in any other way of sulphuretted hydrogen to the evaporating saline solution is the only assumption necessary to account fully for both the presence of iron sulphide in the salt and clays deposited at the time and also for their grey colour as opposed to the more usual red. When the blue clay, or the salt, comes into contact with calcareous alluvium, such as is carried by the brine stream that flows over the Bahadur Khel field, crystals of selenite form. Plate 9 shows such a formation of selenite crystals. It is a photograph of a grey clay band where the surface has had a thin covering of calcareous alluvium washed on to it, with the result that the surface is now covered with selenite crystals, which only occur on the surface of the clay and are not incorporated with it. Below the surface the clay is entirely free from selenite. On exposure to the sun and atmosphere the selenite crystals split into flakes, become stony and opaque, and finally coalesce into a band of gypsum, which in course of time becomes solid, shows no trace of the constituent "devitrified" selenite crystal, and is indistinguishable from the massive gypsum that overlies the salt deposits in order of sequence. Plate 9, fig. 2, shows a number of different stages in this process, starting with fresh selenite crystals in the middle foreground ; devitrifying selenite crystals in the left foreground ; the same at a further stage cemented into a rock, but still showing their characters and distinctly recognizable, in the left background ; and, in the right background, the final stage of massive gypsum. Plate 10, fig. 2, shows a diminutive

cliff of gypsum formed in the same way; to the left there is grey clay, and to the right ordinary recent calcareous alluvium; the gypsum has formed at the contact of the two, and is not yet sufficiently consolidated to have lost all trace of the original selenite crystals. Not only is this instance seen, but, where the salt is covered to any extent with calcareous alluvium, a thick, fairly continuous sheet of gypsum is forming at the junction of the salt and the alluvium at the present day. For instance, at the eastern end of the Bahadur Khel salt-field, where the salt is much covered with thin calcareous sand and alluvium, this sheet of gypsum, formed at the contact plane, is strikingly evident and is sometimes four or five feet thick. Plate 12 illustrates this.

Gypsum forms also in the same way where the salt is brought into contact with calcareous rocks. Along the south-eastern end of the Bahadur Khel field a fault cuts out the gypsum, the red bed, and the nummulitic limestone, and brings the salt against the Murree beds. Gypsum is forming along this fault in exactly the same way as the sheet of gypsum mentioned above is forming in places over the surface. Plate 11 shows a photograph looking west along the fault and it will be seen that the line of the fault is clearly marked by the band of secondary gypsum which in the background forms a hill of marked size. To the left (south) of the gypsum are Murree clays, which are calcareous, and sandstones; to the right (north) of the gypsum band is salt.

Where there is no calcareous detrital material resting on the Bahadur Khel salt, or grey clays, crystals of selenite are not found, indicating that the selenite is not merely recrystallised calcium sulphate, originally present in the salt formation and left behind owing to the removal, in solution, of the salt, but is due to the definite reaction of sulphuric acid with the calcareous material brought into juxtaposition with the salt or grey clay.

It may be thought that I am rather labouring this point of the presence of iron sulphide in the salt and clays, and its decomposition under atmospheric agencies, with the liberation of sulphuric acid, but it will be seen shortly what an important factor it is, in my opinion, in the deduction of the origin and nature of the salt deposits and the gypsum. Another effect produced by the decomposition of this included iron sulphide is the formation of sulphate of soda (mirabilite) by the action of the liberated sulphuric acid on the salt. Plate 22 is a view northwards across the Bahadur Khel field,

taken between the two salt-hills. Most of the white patches on the alluvium in the foreground are sulphate of soda, especially those beside which the men are standing.

Plate 15, fig. 2, shows feathery growths of sulphate of soda breaking through a salt deposit in the site of a dried-up brine puddle on the alluvium. The same feathery crystals creep up the sides of the alluvium above the level of the salt along the sides of the brine stream, and in places break through the salt crust of the stream itself; the same feathery growth forms on the surface of the salt. This efflorescence is not free from sodium chloride—one would not expect it to be—, but its form is due to the creeping and crystallisation of sodium sulphate, and the greater part of the efflorescence consists of that material. From the efflorescent nature of the crystals, and the fact that the fresh salt itself does not contain sulphate of soda, the latter is obviously forming under atmospheric agencies at the surface of the salt, owing to the decomposition of the sulphide of iron contained in the salt and clay particles, and the consequent formation of mirabilite.

In addition to sulphide of iron bituminous matter frequently occurs in the salt. I will quote Wynne on the subject, as I have nothing to add to his observations:

"In the eastern parts of the district the uppermost portion of the salt is frequently bituminous, this salt and the adjacent gypsum smelling strongly of petroleum. The bituminous salt prevails, however, only for a few feet from the upper surface of the deposit, though layers of bituminous or fœtid clay may be found apparently in the body of the salt rock."

I have found this bitumen even in the *shishi nimak* mentioned by Wynne; this is clear salt which occurs in blotches throughout the formation, and is recrystallised salt. In the case that I mention some *shishi nimak* at Malgin contained enough bituminous matter to make it black in colour, and when a thin crystal was held up to the light it was seen that the bituminous matter was arranged as if along planes of foliation through the crystal. The rock appears in fact to be a salt-bitumen schist in which the salt has rearranged itself by recrystallisation, so as to give a sort of semi-pegmatitic structure, the salt being in crystalline continuity, while the bituminous matter, not being of a crystalline nature, is not continuous, but merely retains its original position throughout the recrystallised salt.

Small fragments of gypsum also occur scattered through the salt schist in the Kohat area and form a part of the schist. These

fragments may be secondary and were possibly calcareous clayey material originally.

The points on which my observations differ from those of Wynne and Warth are therefore the foliation of the salt; the widespread presence of sulphide of iron in the Kohat salt, over and above the few instances, recorded by Wynne, of the occurrence of isolated crystals of pyrites; and the discordance between the foliation bands in the salt and the run of the succeeding gypsum formation.

There is one point worthy of notice here while discussing the salt and the presence in it of sulphide of iron. In his memoir on the Trans-Indus salt, Wynne describes an interesting section near Lakkona (*Memoirs, Geological Survey of India*, XI, pt. 2, page 174); he says:—

"An interesting but complicated section is exposed in the Algud (stream which crosses the range running northward in a deep ravine between the Kurar synclinal, and the Speena gypsum tract. Descending this ravine from near Shaidan red and grey tertiary sandstones and clays are passed through, dipping southward at 70°, or more nearly vertical. Red clays of the red zone, with a thickness of 150 feet, underlie these, or would if there was any underlie to speak of. Gypsum, nearly vertical or dipping at a very high angle to the south, 155 feet thick, and with greenish clays on both sides, is then passed. In the lower part of this gypsum the southerly dip lessens to 60°, and the beds are contorted. A few yards further on apparently the same mass of gypsum, curved and undulated, seems to increase enormously in thickness up to 300 or 400 feet, 30 feet of its lowest part being dark, or black, bituminous, calcareous shale. At this place sulphurous springs break out at the sides of, and in, the Algud, the whole place smelling strongly of sulphuretted hydrogen."

I visited these springs and found them to be sulphuretted hydrogen springs as Wynne had stated, but an interesting point that he did not mention is that they are not ordinary fresh-water springs containing sulphuretted hydrogen, but springs of saturated brine, containing also enough sulphuretted hydrogen to make the neighbourhood smell unpleasantly. There can be little doubt that they pass through the salt which underlies the gypsum, and the association of brine and sulphuretted hydrogen is interesting in view of the observation of the presence of sulphide of iron throughout the Kohat salt and its included clays.

Gypsum.

Wynne gives an accurate description of the gypsum. It is generally white, showing up plainly even on dark days at long distances among the hills, but it sometimes has a greyish hue, more rarely variegated with deep

red, from decomposition of iron, and in its lower part often passes into shaly beds, quite black, and smelling strongly of petroleum; its texture varies from sub-compact to more crystalline varieties. As a rule the gypsum is pure and homogeneous, but foreign matter is observable in hand-specimens in places, the chief being grey clay, crystals of iron pyrites, crystals of quartz, dolomite, more rarely anhydrite, and the bituminous portions of the black parts. Associated with the gypsum in the eastern part of the district are one or more bands of alum shales, so charged with pyrites as to have formerly led to their being worked for sulphur, which occurs native in small quantities, the result, apparently, of chemical reaction going on at the places where the shale occurs, and from which sulphurous gases emanate. Closely associated with the gypsum itself are certain thick zones of greenish, sometimes smoothly stratified, clay, often containing translucent crystalline plates or fragments of selenite.

In appearance the gypsum shows every gradation between the sheet that is forming at the present day over the surface of the Bahadur Khel salt-field, and massive compact gypsum. Its stratification is not uniformly evident. In some places the beds appear to be thick and massive, or the bedding laminæ are indistinct. In others it is thinly divided and flaggy. The gypsum of the gypsum formation is indistinguishable from that which has formed along the fault to the south-west of the Bahadur Khel salt-field, and yet the latter has undoubtedly arisen as a secondary product from the interaction of sulphuric acid, set free by the decomposition of the sulphide of iron in the salt formation, and the calcareous material in the Murree beds which are here faulted against the salt formation; the similarity even extends to the presence in both of gypsum in which the decaying selenite crystals are still strikingly obvious.

The lamination of the gypsum is usually contorted and obscure, but where it is well seen it follows the surface of the salt on which it is resting and shows no relationship to the direction of foliation of the salt.

In places gypsum that is not really part of the gypsum formation proper—by this I mean the formation that overlies the salt—has undoubtedly been formed by the interaction of sulphuric acid, set free from decomposing pyrites, and carbonate of lime; as, for instance, in the case of the gypsum around the sulphur mines at Ganjalli on the extreme north-east of the area mapped by Wynne. This

gypsum was treated by Wynne as part of the gypsum formation but I append a photograph (Plate 10, fig. 1) showing a weathered boulder of nummulitic limestone that had rolled down on to the alum shale area; the remains of the coating of gypsum that had formed all round it are still visible in the hollows of the boulder, and this gypsum, which is part and parcel of the gypsum of this locality, was not part of the great gypsum formation that overlies the salt formation. The fact that it has in this instance formed around a weathered boulder of nummulitic limestone, shows that its age is not only subsequent to the nummulitic limestone but to the present arrangement of the rocks, that it is, in fact, recent. In this locality the alum shales are now almost entirely replaced by gypsum.

Origin of the gypsum formation.

No further explanation need, I think, be sought for the origin of the gypsum that overlies the salt formation beyond the view that it has been formed—like the sheet of gypsum over the present surface of the Bahadur Khel field, the gypsum along the fault at the south-west end of the field, and the Ganjalli gypsum—by the reaction of sulphuric acid, set free by the decomposition of sulphide of iron in the salt, on adjacent calcareous material. It occurs exactly where it should occur, if such had been its origin, and the frequent appearance in it of portions in which the partially broken down selenite crystals are still clearly distinguishable, gives it every appearance of having been so formed. thus making it similar in character to the gypsum formed along the fault on the south-west of the Bahadur Khel field. The suggested origin is extremely simple and seems more probable than the suggested derivation from warmed-up mother liquors, or from a solution of calcium chloride coming into contact with water impregnated with sulphate of magnesia or soda. Finally, it is a process which can be seen taking place at the present day whenever the salt comes into contact with calcareous material. It has one important bearing on the geology of the area: it makes the gypsum a subsequent rock—some of it is undoubtedly forming at the present day, if one may judge by the freshness of the selenite crystals—,and not a geological formation that is part of a stratified series. Also it simplifies the geology of the area; for the gypsum then occurs in its proper place above the salt and no longer requires a variety of assumptions to account for its present position. What the exact process is by which the selenite loses its crystalline form and becomes consolidated

into a massive rock, I do not know. I have analysed both the fresh selenite crystals and the gypsum rock for combined water and have found no appreciable difference between them in this respect. But the process may be one of partial dehydration and re-combination with water under the somewhat extreme variations of temperature prevailing here, the crystals losing some of their water of crystallisation in the heat of the day and re-absorbing an equal amount during the cool of the night, or during subsequent rain. But whatever the explanation, the process of change from selenite to massive gypsum undoubtedly occurs, and can be observed occurring.

One of Wynne's observations I was unable to confirm. He states :—

"The alternation of the gypsum with the grey clays is in places very distinct, in others most obscure, and towards the top of the main gypseous band, this frequently passes by alternation of thin layers into the red clay zone which follows. Where the soft clay has been washed from between these upper gypsum layers, as well as occasionally in other parts where the stratification is clear, distinct current or ripple marks have been observed on the surfaces of the beds, indicating their having been accumulated in shallow water."

I have not succeeded in finding any traces of ripple-marks, though the effect of solution on the surface often produces a pseudo-ripple-marked appearance. Even if ripple-marks do exist, I think it unsafe to draw any definite deductions from them, since they may originate in so many ways. Wynne also writes :

"Though prevalent in great, and more or less continuous, masses, the gypsum cannot be said to form an unbroken sheet, its apparent discontinuity being perhaps due to dislocation or denudation, or both. Nor is it limited either above or below by any arbitrary boundary. Thus, in the Malgeen Sáya Hills a layer of salt was seen to separate a mass of gypsum from the rest above; in other parts of the eastern side of the district layers of limestone, or of limestone and clay, were observed near the top of the main gypsum mass; beneath a less strongly developed bed of the latter, and in about the centre of the salt region, thick bands of gypsum occur among the basal beds of the nummulitic series. They are not however constant, and one was traced until it thinned out between the adjacent beds of limestone."

The bearing of the above on my interpretation of the geology of the Salt area is so important that I have ventured to reproduce it.

The Kohat Salt.

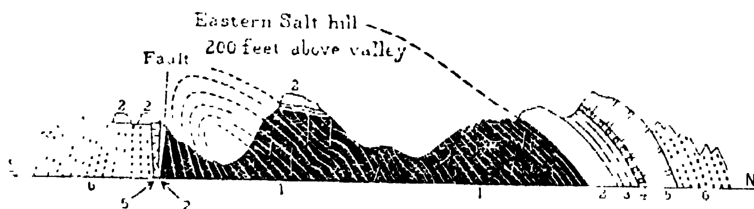
Bahadur Khel.—I do not propose to repeat the whole of Wynne's description but only to explain in what my observations differ from

his. The Bahadur Khel salt-field is about eight miles long and about a quarter of a mile wide. In the western end the salt is more or less bare, whilst in the eastern end the salt is more covered with alluvium. Except in the south-western corner the salt is bounded on both sides by gypsum, followed by the red zone and this by nummulitic limestone and the Tertiary clays and sandstones. In the south-western corner a fault cuts off a corner of the salt and throws it against Tertiary clays and sandstones. I have already discussed how secondary gypsum is forming along this fault, and is already massive enough in places to form large cliffs.

On the salt-field are two salt hills about 200 feet high, each covered by a cap (*see* Plate 8) of greenish-grey clays and gypsum. The gypsum cliffs on both sides of the field are of approximately the same height.

As stated in the preceding paper, the salt of the Bahadur Khel field is a schist and is worked by splitting it along its planes of schistosity. The direction of the foliation planes in the salt is shown on the sketchmap, Plate 8, which also shows that the foliation does not follow the run of the gypsum or of the Red bed or of the Nummulitic limestone. There is in fact obvious discordance.

The section drawn by Wynne to illustrate the structure of the Bahadur Khel salt-field in the neighbourhood of the salt hills is the following :—



1. Rock-Salt. 2. Gypsum. 3. Red clay. 4. Sandstone. Nummulitic limestone. 6. Murree series.

To him, one of the most puzzling things in connection with the Bahadur Khel field was the existence on the top of each of the two central hills of salt of a cap of gypsum having greenish-grey clay interposed between it and the underlying salt. He says (page 145) :—

"It is difficult to account for such appearances as these except under the supposition that before the ground assumed its present denuded form, the

solution and removal of salt beneath allowed portions of the gypsum to slide bodily from their places to lower positions."

On the following page he continues his description of the field as follows :—

Thickness of salt.

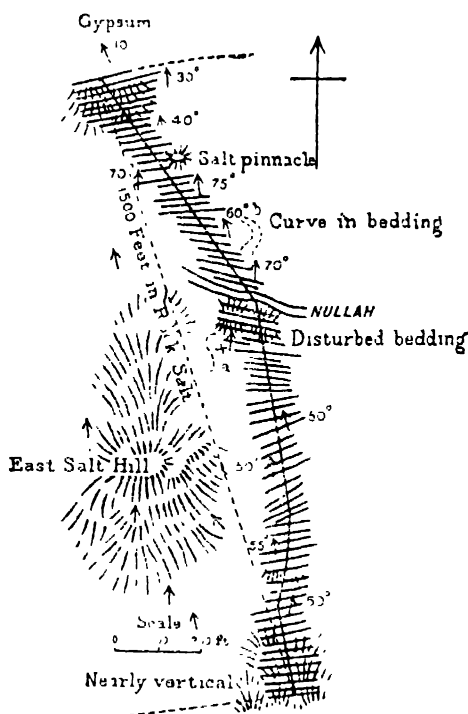


Figure 39 is a reduced sketch of a rough survey from one side of the salt exposure to the other with the dips marked, from which it has been calculated that the thickness of the salt at this place is from 1,000 to 1,230 feet, or even more. Its stratification is almost everywhere distinct, and rendered more evident by thin earthy layers alternating with the beds. Here the dip is everywhere northerly—in the lower beds from vertical to 70° declining to 50° or 55°, forming a bold half arch in the central hills, again high after passing these, but gradually becoming lower to 30°, where the last of the salt is seen. There are only two points, marked *a* and *b* on the plan, where some curvature of the beds or disturbance of the steady high dips occurs, likely to reduce the total thickness of the section, and these curvatures appeared to be quite local, not being traceable for any distance, but though the consecutive high dips follow from bed to bed, the strike is not parallel throughout, a result which may be due to pressure or even to concealed fractures or faults, though no such features could be observed in this section, the only marked divisional planes indeed, besides those of bedding, being some strong nearly horizontal joints.

Gypsum capping central hills, and their relations to the rest of the section.

"The gypsum capping the central hills presents more difficulty with regard to accepting the measured thickness of the salt as true. That to the north succeeds the salt as elsewhere with apparently perfect conformity. The capping on the hills has the same arrangement as already noticed to the west in the interposition of a greenish-gray clay band between it and the salt, and there is, at all events, a certain amount of parallelism among these beds. Still it is clear that if the salt beds to the north of the hill were produced upwards, they would pass, even at a

much lower slope, far above the outlying patches; hence, if the latter are conformable and in their original place, they must either have been embedded in the great salt deposit, or else, being really the lower part of the succeeding zone, the enormous thickness which the salt exhibits must be a false appearance due to concealed faults or to curves the connexion of which is no longer visible.

"But these cappings of gypsum need not necessarily be now in their original places, we have the same rock to the south in utterly abnormal positions, and there is no good reason why these two patches should not also have transgressively subsided from higher levels owing to dissolving of under-lying salt; the situations in which they rested having decided the formation of the hills, to the soluble strata of which they formed a protection against the atmospheric erosion.

Curvature in bedding of salt.

"One of the hills considered by itself presents much the appearance of half of an anticlinal curve, and where inversion is so common (the rule rather than the exception) there would be little difficulty in supposing the salt beds to the southward all inverted, if any clue could be found to the fact beyond the reversed dips of some portions of the series just at the line of fault (already mentioned) where local complication lessens their value.

"By introducing faulting to the north of the hills, the appearances might also be explained with great probability, but of this no evidence has been detected.

Similarity of salt-rock throughout against faulting.

"The similarity of the salt-rock throughout gives it as a mass a unity of character, rendering contortion repeating the same beds more probable than dislocation; a sameness of aspect, too, all but fatal to the hope of discovering repetitions among the layers, more particularly as these are in places strongly obliquely laminated (or false bedded) inducing distrust of discordant appearances.

Possible reduction of thickness incapable of proof.

"However the case may be, the fact remains that a cutting 1,500 feet in length could be made as the shortest straight line from side to side through highly inclined rock-salt and nothing else, except the small quantity of clay associated with it, yet it does seem strange, that while the anticlinal structure pointed out to the west recurs even more strongly about a mile and a half to the east, its disappearance should be at this the widest exposure of the salt, by an apparently enormous thickness of the deposit, and at the same time the clearest evidence of disturbance at the place, instead of explaining this appearance, should be limited to a large downthrow fault at the outer limit of the salt to the south, which it is not easy to connect in any way with the usual thickness of the salt itself, a thickness which, even if capable of reduction from the above considerations, would still remain large, probably from 350 to 700 feet."

The explanation appears to be that the salt is not an ordinary stratified deposit, as I have already pointed out, but is a schist, and

that what Wynne took to be bedding-planes are really foliation planes, and are not bent into a simple anticline, or even a faulted anticline, as he supposed, but have the structure shown in the accompanying sketch :—

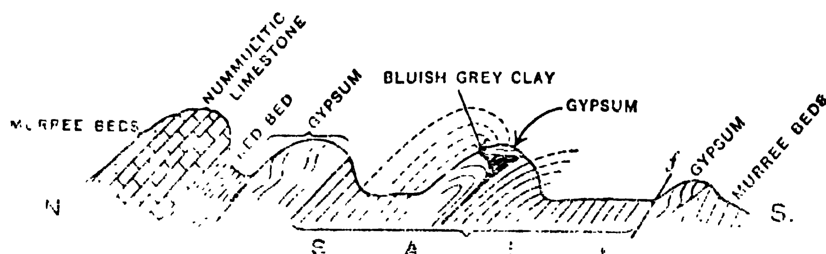


Plate 14 is a drawing from a photograph and shows the sharp bend over of the foliation planes to the north on the northern side of the salt hill. Plate 15, figure 1 shows a nearer view of the same hill.

The eastern side of the hill shows the same sharp bend over of the foliation planes to the north. In this case the complexity of the bending and folding is strikingly evident. Plate 15 is a near view of the north-east side of the hill and shows the folding in greater detail.

It would seem therefore that the salt of the Bahadur Khel field is not only foliated but has been overfolded by movement from the north : probably the same movement that ridged up the rocks of the country into the long steep east and west anticlines and synclines that are the feature of the area. The explanation of the two salt hills of the field being capped by gypsum follows as a natural sequence. The salt was overfolded and the line of the reversed limb runs through the two hills. Its course is indicated on the sketch-plan of the field, Plate 8, by the line of clay which occupies a more or less central position along the western end of the field for some distance east and west of the hills. The sketch-map shows also the difference in the complexity of the foliation to the north and south, respectively, of this overfold, the foliation being much more complex in the northern half of the field than it is in the southern, this again seeming to indicate a thrust from the north. As shown on the map, clay was caught up in this overfold and now occupies an irregular

course along the position of the fold. This clay is not a uniform band; sometimes it is pulled out to the finest string, and in other places it occurs as thick lenticular patches. Two such patches apparently occurred in the original undenuded salt in the positions occupied by the clay caps to the two hills; during denudation these clay lenticles came into contact with calcareous material and a covering of gypsum was formed. The clay and overlying gypsum then formed a protective cover, or umbrella, and shielded the salt underneath from subaërial denudation. The surrounding unprotected salt was denuded, and so the two hills were left standing above the level of the rest of the field. The fact that the two hills and the gypsum hills bounding the field are approximately of the same height makes it probable that the height of the hills represents the amount of denudation that has occurred in the field, and that if we knew the approximate rate at which the level of the field is being lowered at the present time we could approximate to a rough estimate of the period that has elapsed since denudation first began to operate on the field.

The field was extensively tested for the presence of potash but none was detected. This indeed is only what might have been expected, for, just as the original clay beds appear to have been sheared across, and the brecciated fragments strung out along the foliation planes, with the result that the clay now occurs as isolated fragments which are integral constituents of the salt schist, so potash, if any seams of it existed in the original beds from which this salt schist was formed, would also exist now as isolated particles scattered through the schist. As already stated the failure to detect any in the schist may mean that no beds of potash existed in the original beds from which the schist was formed, or it may mean that, being more deliquescent than salt, and the salt schist being distinctly pervious to water in places, any particles there may have been in it may have been removed in solution.

In the preceding paper I have given details regarding the Malgin, Jatta and Nandrakka exposures and have pointed out that the last-named are intermediate in type and seem to form a link between the two salt areas, thus giving rise to the presumption that the two salt deposits are part of one great salt formation and are not distinct and unconnected formations.

The Punjab Salt.

I have also already pointed out that the Punjab salt is red and occasionally grey, and generally contains salts of magnesium and potassium. Its usual position is below the Purple Sandstone of the Salt Range, which underlies the Obolus Shales of undoubted Cambrian age. Occasionally it is overlain by Nummulitic limestone, as at Vasnal in the Jhelum district, or by Tertiary sandstones and clays, as at Kalabagh. But in every case, just as in the Kohat area, it is the lowest formation seen, and nothing has ever been found definitely underlying it. In the Punjab the salt occurs in a peculiar red marl and the junction between this Salt Marl and the Purple Sandstone is a disturbed one, generally marked by a breccia. The relationships of the Salt Marl to the other rocks have been throughly investigated by Middlemiss (*Rec. Geol. Surv. Ind.*, XXIV, pt. I, 1891), who found that the normal junction was a breccia, and that occasionally the Salt Marl behaved as if it had been injected or squeezed into abnormal positions in the overlying rocks. I cannot do better than quote him on the point. He says :—

Alleged passage of the Red Marl into the Purple Sandstone.

"Mr. Wynne, though unable to find in the range or elsewhere any evidence of what lies beneath the Red Marl, does not appear to have had any misgivings as to the relation of the Red Marl to what comes above it. He states (p. 85) that the Red Marl apparently passes up into the Purple Sandstone. If therefore, my efforts to show that the marl is not in normal stratified succession beneath the Purple Sandstone are to be successful, I must show this apparent passage to be unreal.

Interbedding the best proof of continuous sequence.

"Now continuous sequence between two formations is best established by the one formation being found *interbedded* with the other. But there is no such continuous sequence as this between the Red Marl and the Purple Sandstone—no alternating layers, first of marl and then of sandstone, dovetailing the two together. The very few isolated and doubtful cases in which some apparent interbedding takes place are justly mentioned with considerable reserve by Mr. Wynne himself. Speaking broadly, there is no interbedding between the two."

No petrological passage.

"The only sense then in which the Red Marl could be said to pass up into the Purple Sandstone would be by the existence of an intervening layer of rock petrologically neither a marl nor a sandstone, but a mixture of the two. And this is what Mr. Wynne relies on to show the above passage. For my own part I could never satisfy myself of such a passage bed indicating continuous sequence. I admit that in nearly every section of the two rocks

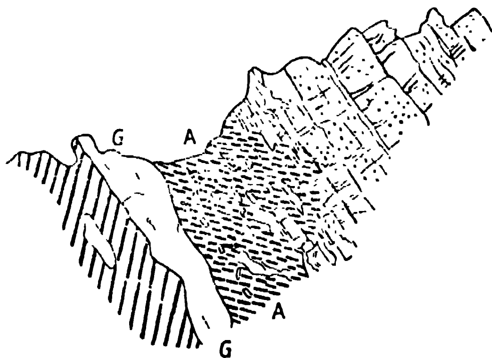
in contact there is what at first sight might be mistaken for a passage bed, but which I was able to determine at very many places to be of an entirely different nature.

True nature of the junction of the Red Marl and Purple Sandstone.

"The Red Marl, from its proneness to soften at the surface when rain falls upon it and to become in consequence much mixed up with fragments of rocks from the cliffs above, is generally a difficult rock to study. In a country less arid and bare indeed, it would be almost impossible to find a natural section of the rock free from its load of surface *débris*. As it is, there are occasionally exposed reliable junction sections of the Red Marl and Purple Sandstone in close conjunction. In every one of these the layer of rock at the junction is *brecciated*—such a junction in fact as might be understood in a variety of ways *other than* that of the natural deposition of the Purple Sandstone conformably above the Red Marl. I will now detail some sections, which will, I hope, tend to clear up the mystery in part at least.

Junction exposure north-west of Khewra.

"The first instance I will give occurs at the north edge of the exposure of Red Marl west of the main road from Khewra to Choya-Saidan-Shah. It is a continuation of the band of Red Marl which crosses the road about two miles north-west of Khewra railway station. On descending into the depths of the little cañons among the masses of white and red rock mixed largely with surface *débris*, we find at the north edge of the marl, where it comes in juxtaposition with the Purple Sandstone, an arrangement as seen in Sketch Section No. 3, Plate III. To the right of the section there is the massive, well-bedded Purple Sandstone, which, as it approaches the marl, becomes much shattered, more like a rock approaching a fold-fault than anything else that I can think of. The masses of the sandstone first keep a rough parallelism, though broken across, shattered, and detached from the consecutive layers of sandstone. Further on, towards the marl, there comes a well-marked layer, 3 or 4 feet across, AA of the section, in which the fragments of Purple Sandstone are smaller, though keeping their angularity and turned about in all directions; the matrix in which they are scattered being a mixture of what appears to be powdered-up portions of the sandstone mixed with Red Marl. This abruptly ceases, and a band of gypsum, G, follows, and then a layer of the pure amorphous Red Marl.



SKETCH SECTION No III.

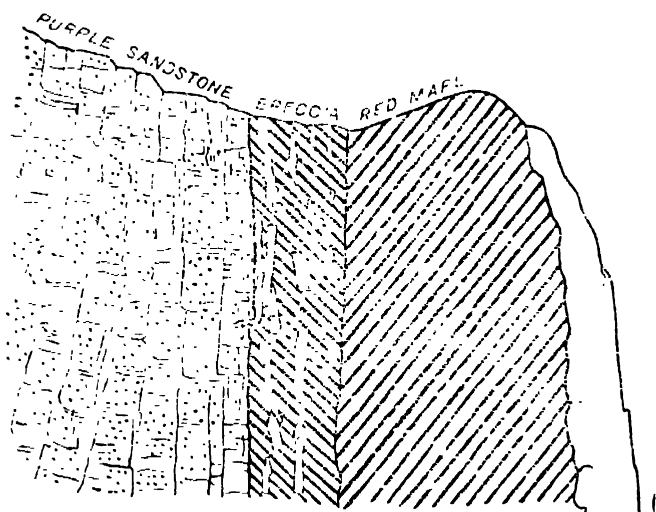
"The junction layer AA is an important one to which attention must be drawn. Its internal evidence proves that it was formed subsequent to the contained fragments of Purple Sandstone, which oriented, as they are, in all directions, nevertheless keep their individuality in a most perfect way. We must, I think, conclude that it is of the nature of a breccia, and marks a line of relative movement between the two formations.

Junction exposure north of Khewra.

"A similar section up the Khewra glen, where a mass of very pure Red Marl underlies the Purple Sandstone at a much lower angle, presents the same features, there being a distinctly brecciated band a few feet wide separating the sandstone from the marl.

Junction section at Kavhad.

"At Kavhad, where the glen bifurcates, there is also a very good exposure of the above rocks in conjunction. This is illustrated in Sketch Section No. 4, Plate III. On the left is good, strong, normal Purple Sandstone,



SKETCH SECTION No IV

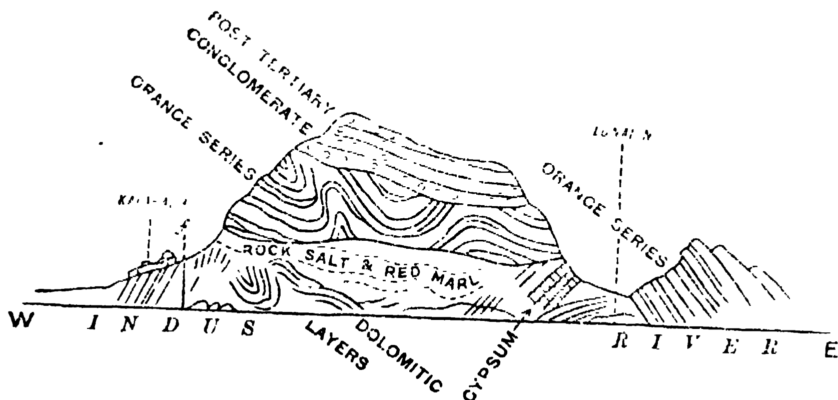
sometimes veined with pale green tints, whilst on the right is bright, scarlet and sometimes vesicular Red Marl, of a wavy tufaceous aspect, already described (see *ante*). In between the two comes a zone which in the distance often has the appearance of a passage, as stated above. It is two yards across, and is in truth half marl and half purple sandstone, but in this way the two are not interbedded in the ordinary sense of the term, nor is there a gradual passage from the one rock into the other, but there is a matrix of reddish and greenish marl which is stuck full of fragments of Purple Sandstone, sometimes roughly indicating bedding. Certainly, all the fragments are angular and lie more or less in the direction of the general bedding, but there is no suggestion of a passage from the marl to the sandstone. The appearance in fact is just that of a brecciation of one rock by intrusion of a later one among it. This line of junction can be followed along

the glen for some way up stream. I have selected it for description partly on account of the verticality of the beds in a cliff section, which can be trusted as being entirely free from surface re-arrangement.

"These three examples may, I think, stand by themselves as sufficient proof of the general statement that I have made, to the effect that there is never any real passage upwards from the Red Marl to the Purple Sandstone."

Mr. Middlemiss also describes in detail numerous instances where he regards the Salt Marl as having been squeezed into abnormal positions and as now occupying the core of inverted flexures or the line of the middle limb of a sigmaflexure, or the line of a tearing or thrust which has followed on the formation of the sigmaflexure.

He mentions[1] also the following section at Kalabagh which obviously means either overthrust or intrusion of the Salt Marl:



"The . . . section at Kalabagh . . . . has always been a puzzle of no simple order on the accepted idea that the Red Marl is the basal formation of the Range. I have copied it from Mr. Wynne's own drawing (Memoirs of the Geological Survey of India, Vol. XIV, p. 269), as it is not his observations but his conclusions which must be called in question with regard to it. I have, however, altered the index names of the conglomerate and the Tertiary Sandstones, in conformity with later observations made by Mr. Wynne and by Dr. Waagen.

The section at Kalabagh.

"It will be observed that in that section the orange coloured beds (called the Orange series by Dr. Waagen in his Geological Results, Vol. IV, Part I) are in direct superposition on the red, white, grey, or bluish-grey rock salt of the Saline series.

"I infer from the following considerations that this junction cannot be a normal one due to the deposition of these beds on the top of some exposed reef of Salt Marl:—

(1) The Orange series, whatever be their particular age, undoubtedly belong to the younger Tertiary epoch, and may with certainty

[1] *l. c.*, p. 37.

be placed stratigraphically somewhere above the Nahan Sandstone and somewhere beneath the Upper Siwalik Conglomerate. Stated differently, they are the middle portion of a geological and petrological series, of immense extent and thickness, which covers vast regions on the North-West-frontier, along the southern borders of the Himalaya, and in Assam and Burma. Throughout this great extent of territory the middle rock-stages of that series are never found in superposition above anything but a lower stage of the same series. What is perhaps of more importance for the present argument, is that in the immediate neighbourhood of Kalabagh, along the very wonderful and striking section up the Indus river from that place, the same fact is above all manifest. There is no trace of unconformability in it.

(2) A still more comprehensive local generalization may even be made. The Tertiary system, as a whole, though showing a distinct break between the Nummulitic Limestone and the Nahan Sandstone, does not anywhere in the Punjab exhibit the Nahans superposed above anything but nummulitic strata. Thus, there is no parallel instance anywhere in the Empire on which to frame a line of marked unconformability among the middle stages of the Upper Tertiaries, and we must therefore admit that the abnormal junction of the Orange series on the top of the Saline series is not due to the position of the Orange beds above, but to that of the Saline series beneath.

(3) A further point strengthening this conclusion is that the Orange coloured beds, composed of soft sandstones and clays, or shales, begin as such immediately in contact with the salt-bearing beds. There is no basal conglomerate, and there is no gradual or rapid change downwards in the nature of the sediment of the Orange series as the Saline series is approached—nothing to indicate the beginning, at this point, of a set of detrital rocks of such marked features and extent as those of the Upper Siwaliks.

"A painting with the foreground and middle distance cut away would not more plainly indicate mutilation than does this ruptured section of the Orange beds.

"According to Dr. Waagen, the whole of his Red series, Grey Sandstone series, and Purple series, which come beneath the Orange series, are absent in this Kalabagh section, whilst they are in full thickness further up the Indus river.

"In the Sketch Section above I have copied from Mr. Wynne's figure, because I think it truly represents the relation of the rocks visible on the river face. In his Trans-Indus memoir (Memoirs, Geological Survey of India, Vol. XVII, part 2, p. 46) a section through the same hill, but along a different line, is given. As it primarily represents other points, the above relation of the Orange series to the Saline series is not given due prominence."

As a matter of fact, from a close investigation of this section in the field, I believe that most of the apparent contortion of the

Orange series, is false and is merely a deceptive appearance given by uneven slipping of the outcrop down the steep slope of the hill. This, however, does not upset Middlemiss' deductions in any way, and is merely mentioned as this section is so often quoted.

From the above facts it may be taken, I think, that the junction between the Salt Marl and the overlying beds in the Punjab is not either a conformable one or a simple unconformity, and the inference seems unavoidable that movement has occurred along the junction, and that a certain amount of intrusion has occurred, the Salt Marl having been squeezed in places into flexures and fissures in the overlying rocks.

The Salt Marl has been thoroughly studied by Middlemiss and again I have nothing to add to his observations, the most important of which are[1] :—

Mr. Wynne's description.

"The Red Marl, with its immense masses of rock salt and gypsum, has been very thoroughly described by Mr. Wynne in his memoir, pages 70-84. I shall cull a few of his paragraphs as being of special interest, or as bearing on the present theory. Of the Red Marl itself, he gives Dr. Fleming's remarks on its chemical composition, which run as follows :—

'It does not disintegrate when treated with hydrochloric acid, but in powder effervesces strongly, the greater part remaining undissolved as a red mud, composed of clay and sulphate of lime; the portion soluble in acid consists of carbonate of lime and carbonate of magnesia in about equal proportions with a little alumina and peroxide of iron, to which it owes its colour.'

"Mr. Wynne concludes from the above that the term "gypseous marl' is not inapplicable. As to its petrological nature and aspect he writes—

The marl forms the most noticeable portion of the saline group, but in close association with it are thick beds of gypsum and thicker ones of rock salt. It is tough rather than hard, but when very dry, possesses much the consistence of sun-dried brick.

"He further writes—

'Beyond the gypseous, saline, and dolomitic layers the red marl bears few original traces of stratification, or inter-stratification, generally none at all; hence it is difficult to form any correct idea of its thickness. * * * It may be doubted whether another example could be found of such a homogeneous, argillaceous and aqueous deposit of the same depth in which signs of stratification are equally absent. In strong contrast to this is the perfect lamination frequently seen in the enclosed salt,

[1] *Ibid*, p. 27.

and in the platy dolomitic layers. From the contorted state of the latter and the curvature of the beds of salt in some of the mines, it may be presumed that, whether stratified or not, the salt marl is likewise disturbed.'

No divisional planes.

"It is necessary to emphasize some of the points quoted above. So far as I have seen, I should say that the Red Marl, except when it encloses masses of the dolomitic rock, or when it is in combination with beds of gypsum and rock salt, *never* shows any stratification whatever; nor is there the slightest trace of any divisional planes in it. On taking a lump in the hand, the broken edges are precisely such as one would get in any structureless, amorphous mass. The likeness to a sun-dried brick mentioned by Mr. Wynne applies as much in the matter of homogeneity as in hardness. Seen in large masses on the hillsides, it equally displays a lack of structural planes. In this respect it differs from limestone and other similar, chemically formed rocks; for a compact amorphous limestone, though evincing but little trace of stratification in the hand specimen, very often gives to the surface of the earth either a scarp, cliff, or moulded slope, by which its obscure planes of original deposition can be discerned. But there is no such hint thrown out by the Red Marl. Denudation acts on it as it would on a heap of sand, making streamlets here, and rough hillocks there, the former winding in a capricious manner, and the latter strewing the slopes at random.

No colour banding.

"With the absence of divisional planes there is also an absence of colour banding. The Red Marl, though varying somewhat in the brilliancy and depth of its colour, is of one general hue throughout. There is no parallel system of tints, such as the colour banding of slates (which reveals the original stratification of the slates, although the power to split along it has been taken away).

* * * * * *

Positive evidence.

"...... I have some new facts to bring forward now regarding the interrelations between the dolomitic layers and the Red Marl on the one hand, and the dolomitic layers and the gypsum on the other.

Absorption of the dolomite rock by the Red Marl.

"At Kavhad there is a good exposure of the Red Marl showing the following peculiarities:—(1) Its brick-red colour and homogeneous aspect is broken by a net-work or sponge-work of filmy, anastomosing strings of gypsum; (2) The pale grey dolomite involved in the Red Marl is not disposed in continuous beds but in vesicular or honey-combed lumps, of irregular shape and size; (3) The bright red matrix, if examined carefully, is seen to be dotted all over with pale greenish grey patches. Some of these are as large as an inch across but most of them are mere specks. It is noticeable, however, that these specks are drawn out like the spattering of a pen, and that in their course through the rock they keep very generally a more or less parallel direction for a short distance, but waving about. They give an irregular streaky and patchy appearance to the marl, as if the former had been kneaded up with the latter, just as patches of white bread are sometimes found incorporated by mistake in a

loaf of whole meal flour. But the most important point in connection with these grey specks is that they may be traced by every gradational form into disintegrated patches of the honey-combed dolomite. The latter, in its larger pieces, is as distinct from the marly matrix as an included fragment of schist often may be in a granite; but as these lumps become more honey-combed, and more vesicular, they split into groups of three or more straggling and corroded [1] remnants of dolomite, and these again into clusters showing a gradual change into the greenish-grey specks previously mentioned. In the latter condition they are one with the Red Marl. The Red Marl in fact seems to have devoured the dolomite, to have absorbed or digested it, just as a pot of molten lead absorbs the solid bits thrown into it. Of course the actual process of the transformation described above is not seen, but only the various stages which I have thus vivified for facility of description.

Passage of beds of dolomite into gypsum.

"A parallel change from the dolomite into gypsum is also indicated by numberless passage forms at a great many places in the Salt Range. Two miles north of Buri Khel there is a good example. The dolomite, roughly bedded in some places, solid in its central portions, but crumbling and honey-combed at the edges, occupies areas of many square yards among the gypsum and Red Marl. The smaller patches of the dolomite exhibit the following stages of change:—(1) the hard flinty-looking rock becomes dotted with minute punctures, either in rows or nebulous patches. These holes are as fine as a pin-point. (2) In the near neighbourhood another lump of dolomite may be taken in which there are larger ragged holes, such as appear in a moth-eaten garment. Close examination shows that these larger holes are bordered by the minute punctures, and indicate that the former were made by the close approximation and fusion of the latter. (3) Joining these larger ragged holes there run canals sometimes roughly following joint planes in the dolomite. (4) Another stage of change may be seen by the dolomite assuming a honey-combed structure, somewhat resembling pumice in which the holes are larger than before. At the same time the joint planes at right angles to one another are converted into widened fissures cutting up the lump into irregular cubes and masses, gypsum taking the place of the dolomite along the cracks and holes. (5) Groups and strings and lumps of the dolomite in the final stages are honey-combed to a spongy and then to a reticulate fibrous texture, the holes and meshes being occupied by gypsum.

"I take it as beyond dispute that the one rock has gradually replaced the other original rock, probably by some metamorphic change that finds a parallel in the well-known example of laterite formed from gneiss. It would thus seem that, according to circumstances, a genuine stratified deposit of dolomite has been converted, either into a pure gypsum, or into a less pure gypseous marl."

It will be observed that the mode of formation of gypsum, as described by Middlemiss, agrees perfectly with that of the Kohat

"[1] I use the verb 'to corrode' here in a general sense for want of a better word."

gypsum observed by me, and no further explanation seems necessary if the two salt deposits are really parts of one formation.

The gypsum.

There is nothing new to record about the gypsum. It agrees in character in every way with the Kohat gypsum except that a pink colour is perhaps more common. Here, as in Kohat, abundant instances can be found of half-formed gypsum, intermediate in character between selenite and gypsum rock and showing clearly the breaking down or devitrifying selenite crystals. As in Kohat too, the gypsum contains not only foreign minerals, such as the famous bipyramidal quartz crystals of Mari and Kalabagh, and the Lun Wan pass into Kohat, but also incorporated foreign rocks such as dolomite, and grey shales, as at Kalabagh, and even trap as at Khewra, where trap, apparently unconnected with anything else, occurs in the gypsum. The gypsum often occurs in a disconnected way through the Salt Marl and its relationships with the marl and the salt are difficult to determine.

The salt.

As already stated the salt does not occur in regular stratified beds, but in lenticular and irregular bands having a foliated character, the foliation, however, being on a much larger scale than is usually associated with that term ; and whereas in Kohat the foliation is such that the rock can be called a schist, in the Punjab it is on such a large scale that the individual bands are feet and sometimes yards across, and the foliation suggests flow structure.

The variation in thickness and the discontinuity of the potash bands at Nurpur have already been referred to in detail in the preceding paper, in which I have also pointed out that in the Mayo mine at Khewra the banding of the salt does not appear to be due to ordinary stratification. The first thing that struck me on going into the latter mine by the main entrance was the appearance of frequent marl bands in the salt. These cut the new tram tunnel obliquely and give a striking appearance of flow structure. The marl is strung out in streaks that twist and ramify and coalesce exactly as the streaks in a solidified magma showing flow structure, and they surround and include lenticular patches of salt, all arranged, with their long axes parallel to the apparent direction of flow. Whatever they are due to, one realises at once that the present arrangement of these particular parts of the salt formation is not due to original stratification.

An examination of the banding in good salt showed that here also it does not conform to the laws governing ordinary sedimentary strata. I attach a photograph to illustrate this. Plate 20 shows what is called well stratified salt. On studying it, it is seen that the bands are not regular stratified beds, but that they thicken and thin and branch into other bands as beds of deposited salt could not do.[1] I may add that I have never seen anything of the nature of false bedding occur in crystallizing salt. There is a brine stream running over the Bahadur Khel field and depositing salt by evaporation. The stream is shallow and flows fairly swiftly, but no sign of false bedding appears in the deposited salt on its floor, or bed. Each crystal is firmly fixed in the place where it first began to grow, and there it remains cemented to the other salt on which it lies, and no movement such as might produce the effect of false bedding is possible. I am loath to admit therefore that false bedding could occur in deposited salt beds[2], but in any case it would not explain this particular instance. Plates 18 and 23 show the bands of marl that occur in the salt; they show clearly that they are not stratified beds. Finally Plate 19, figure 2 taken in the new lower tunnel that is just being run, and showing some of the lowest Salt Marl exposed in the mine, strongly suggests flow structure rather than stratification.

Thus, everywhere the salt apparently shows signs of foliation—most intense in the Kohat area and least in the Punjab—and nowhere does it seem to be entirely unmetamorphosed.

III.—GENERAL DEDUCTIONS.

I am of opinion that the salt in the Punjab, and Kohat, all belongs to the same period, and is part of the same formation, and that the overthrust suggested by Sir Thomas Holland as occurring between the salt deposits and the overlying rocks in the Salt Range (*op. cit.*) undoubtedly occurs, but that it extends through Kohat as well, its age being, of course, earlier than the folding movements which ridged up the Kohat rocks into their existing arrangement of steep anticlines and synclines.

[1] The lenticularity is much more obvious if the photograph is looked at from a distance of four or five feet.

[2] Wynne also records the fact that "no sign of current mark or well-developed oblique lamination could be found" in the salt deposits. *Mem. G. S. I.*, XIV, page 78.

The brecciated junction between the Purple Sandstone and the Salt Marl, and all the various abnormal occurrences noticed by Middlemiss and Wynne, are explicable on the assumption that there is an overthrust bringing the other rocks on to the salt—a view that is greatly strengthened by the existence of subsidiary overthrusts in the salt itself at Khewra and Nurpur.

Up to the present it has merely been shown that the gypsum not only need not be, but does not appear to be, a geological formation following on the salt in natural order of sedimentary sequence; but that, on the contrary, it may be a contact mineral formed at the junction of the salt formation with other sediments containing calcium carbonate or holding water carrying calcium carbonate in solution. This being realized not only as a possibility but as a probability, its influence on the reasoning applied to the salt formation is of great importance. So long as it was assumed that the gypsum was a normal geological formation having its place in a definite and conformable stratigraphical sequence, the conclusion was unavoidable that the salt exposed underneath the gypsum must all belong to the same horizon, or approximately so. But if the gypsum is not a stratigraphical formation but a contact mineral formed by chemical reaction subsequent to the deposition of the overlying beds, then the possibility becomes apparent that the salt found beneath it in the various exposures need not belong to the same salt zone or horizon, unless the strata overlying the gypsum are always the same and conformable to the salt, a condition which certainly is not the case.

Further than this, if the gypsum is a subsequent rock formed at the junction of the salt deposits and the adjacent rocks, then all the various foreign rocks that occur in it, or partly in it and partly mixed with the topmost layers of the salt, such as the bituminous salt and gypsum of Kohat, the alum shales on the north-east of the Kohat area, the dolomitic beds, the greenish grey calcareous clays, and even the trap at Khewra, can be regarded as fractured and isolated patches of rock that have been caught up and carried forward along the line of the overthrust. The corrosion of the dolomite that was such a puzzle to Middlemiss needs no further explanation; and the confused arrangement of salt and gypsum observed by Wynne in Kohat, and in the upper layers of the Salt Marl, is to be expected.

The simplest interpretation of the evidence at present available then, seems to be that the sedimentary formations at present overlying the salt have been brought into place by an overthrust, and that along the plane of this overthrust secondary gypsum has been formed by the reaction of calcareous material in the sediments with the sulphuric acid formed by the decomposition of iron sulphide in the salt formation. Now if the salt were orignally deposited from an evaporating saline solution, which I agree with Wynne and Christie in thinking was the case, it is improbable that it would be of uniform composition throughout, but it would have been deposited originally in zones. An example of this may be seen in the Stassfurt deposits of Germany. F. Bischof divides the Stassfurt beds proper into four regions vertically, corresponding, he observes, to the natural order of origin from an evaporating solution[1] :—

(4) the carnallite zone,
(3) the kieserite zone,
(2) the polyhalite zone,
(1) the anhydrite zone ;

and if the Indian salt deposits were deposited from solution, it is probable that they too followed originally some such arrangement as that detailed by Bischof. Subsequent alteration and metamorphism in the Indian deposits might alter the actual mineral constituents of the zones, but nevertheless some kind of differentiation into zones should still be recognizable in the Indian deposits. Viewed from this standpoint, the different constitutional characters exhibited by the different salt exposures in the Salt Range and Kohat become significant. It becomes no longer necessary to try and find reasons why the salt in different places exhibits different constitutional characters, and the probability becomes clear that these differences may be explained by the fact that in the different exposures the salt represents portions of different zones or horizons in the original salt formation. For instance, the Kohat salt deposits exhibit different characteristics from the Kalabagh salt, the Kalabagh salt from the Warcha salt, and the Warcha salt from the

[1] *Ann. Chem. Phys.*, 5,305, 1865; *Berg-und hüttenmännische Zeitung*, Leipzig, 24, 1865.
See also H. Everding, *Deutschlands Kalibergbau*, page 36, 1907.

Nurpur and Khewra salt, and these differences may be due to the fact that the Kohat salt, the Kalabagh salt, the Warcha salt, and the Khewra salt each represent a different horizon or region of the original deposits. This I believe to be the case, and though no exact parallel can be drawn with the Stassfurt deposits, nevertheless a certain similarity can be observed in the differences exhibited by these presumed zones and the differences exhibited amongst the recognised zones of the Stassfurt deposits. The Kohat salt deposits on analysis show the presence of calcium sulphate but no potash or magnesia, and this would seem to imply that they represent a low horizon of the original deposits corresponding to the period when only calcium sulphate and sodium chloride were being deposited. The Kalabagh deposits begin to show traces of potash and magnesia, but no recognizable thickness of these latter salts has been found; they are merely found in brine pools in some of the mines, having obviously been dissolved from the particular salt in which the mine is situated. Calcium sulphate is still common in the salt.

The Warcha salt differs from the Kohat salt and the Kalabagh salt in that it contains a large quantity of magnesium sulphate and a certain amount of combined magnesium and potassium sulphates. The outstanding feature of the Warcha salt is, however, magnesium sulphate. The Khewra and Nurpur salt does not contain so much magnesium sulphate, but contains potash compounds in a higher percentage compared to magnesium sulphate than the Warcha salt. It, therefore, seems that the suggestion that these different exposures of salt represent different horizons of the original salt formation is justified, and that their relationship to one another in the original vertical section of the salt deposits may have been approximately the following:—

(*d*) the Khewra salt zone,
(*c*) the Warcha salt zone,
(*b*) the Kalabagh salt zone,
(*a*) the Kohat salt zone.

An exact parallel between these zones and the Stassfurt zones cannot, of course, be made, but I suggest that the Kohat zone corresponded probably originally with the anhydrite zone of Stassfurt, the Kalabagh zone probably to something between the anhy-

drite and the polyhalite zones, the Warcha zone to something between the polyhalite and the kieserite zones, and the Khewra zone to about the kieserite, or something between the kieserite and the carnallite zones.

The foliation of the salt may be due to overthrusting, at least in part; and the fact that the foliation is most intense in Kohat and the discordance between it and the strike of the overlying Tertiary beds most marked there, seems more than significant when it is also realized that in Kohat the salt deposits do not follow the run of the Salt range, but swing away to the north-west from Kalabagh, while the trans-Indus continuation of the Salt Range continues westwards and southwards across the Indus.

The next point for consideration is the age of the salt deposits. Wynne put the age of the Punjab salt as pre-Purple Sandstone, *i.e.*, approximately pre-Cambrian, and, in view of the fact that in the whole section of rocks above it there is neither a repetition of the salt nor of continental, desert or salt-lake deposits, it seems improbable that the age of the salt is post-Purple Sandstone. Moreover in Kohat the great salt deposits occur within ten miles of the Trans-Indus continuation of the Salt Range in which neither the section of the Tertiary rocks, nor of any of the rocks exposed down to the Permo-Carboniferous, gives any evidence of salt-lake conditions. So that it seems reasonable to suppose that the Kohat salt is at least earlier than Permo-Carboniferous in age, a conclusion that does not disagree with my supposition that the salt in the Punjab is pre-Cambrian. I therefore place the age of the salt formation as pre-Cambrian. Whether any connection can be traced between the "sulphur" period of the salt deposits indicated by the Kohat zone, and the volcanic activity of either Vindhyan or Bijawar times, or whether the Purple Sandstone is part of the desert sands that must have accumulated during the salt period, and has been brought forward on to the salt by the overthrust, and is thus approximately contemporaneous with it instead of subsequent to it in agé, are matters of conjecture; but the evidence, in my opinion, points to the salt deposits having formed about that time, and being of either Cuddapah or Vindhyan age, or possibly astride the two periods.

I am aware that my views necessarily increase the estimated thickness of the salt deposits as a whole; but in salt that has been

foliated and has been folded and overfolded in places, it is impossible to estimate the original thickness of the beds.

With reference to the Khewra mine, although I regard the salt exposed in the mine as belonging to the kieserite and possibly partly to the carnallite zones, it does not necessarily follow that the Warcha and Kalabagh zones will be found underneath it, since at the bottom of the deep exploration drift in No. 12 Pharwala, what appears to be a fault-breccia is found along the line of subsidiary overthrust, and below it is grey salt; and it looks as if the equivalents of the Warcha and Kalabagh salt might have been cut out by the subsidiary overthrust.

The age of the gypsum is uncertain; it may be anything from that of the overthrust to the present day. Much of it is undoubtedly recent, and some is forming now. Probably the truth is that the formation of the gypsum extends over the whole period from the time of the overthrust to the present day, its formation being quickest along exposed and denuding junctions.

IV.—SUMMARY.

The observations seem to fit into and support one another, and to leave little unexplained; they seem also to point to the inference that the salt was originally sedimentary in origin and belonged to one formation. The chief arguments in favour of this are :—

(1) the Kohat salt is grey; the Nandrukka salt grey with bands of pink salt; the Kalabagh salt red with bands of grey salt; and the Punjab Salt Range salt red;

(2) the salt in Kohat contains calcium sulphate, but no potassium or magnesium compounds; the Nandrakka salt contains traces of potassium and magnesium, as well as calcium sulphate; the Kalabagh salt contains more potassium and magnesium compounds, but still only in small quantities, and calcium sulphate; and the salt stalactites on the mines frequently have a "cotton-wool" appearance due to the presence of sodium sulphate; the Warcha salt contains combined magnesium and potassium sulphates; while the Nurpur and Khewra salt contains no combined calcium sulphate, but sulphates and chlorides, both combined and free of magnesium and potassium;

(3) the foliation and schistosity of the salt is greatest in the western part of Kohat, and gradually diminishes in an easterly direction, until it is least evident in the eastern end of the formation around Khewra; this may arise from the overthrust being greatest in Kohat and least on the east of the salt area.

The above observations coupled with the fact that an evaporating saline solution deposits salts in successive zones, each differing from the one below it in mineralogical composition, in the order given by Bischof, suggest that the rock-salt of Kohat and the Punjab belongs to one great salt formation, and that the differences in character of the salt exposed in the different exposures are due to different zones of the salt being exposed at different places. It is suggested that the Kohat salt belongs to approximately the lowest zone, and there may be a gradual transition through salt which originally belonged to higher and higher zones in the original stratified section until, at Khewra, salt which may have belonged to the kieserite or possibly to the carnallite zone, is met with.

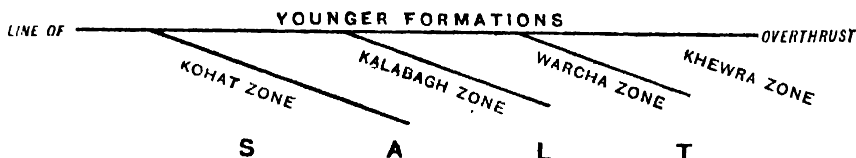
Since they have apparently undergone metamorphism, and since this metamorphism affects the included potassium, magnesium and calcium compounds chiefly, it is obvious that an exact parallel cannot be expected between the mineralogical composition of the Indian salts and unmetamorphosed deposits such as those of Stassfurt. There is a certain apparent parallelism, but not enough to make it desirable to adopt Bischof's nomenclature. It is more convenient to give the different salt zones assumed here names that will have more meaning in these particular deposits. It is now suggested that the salt was deposited in a great salt lake by evaporation, and in zones comparable to those of Bischof, but that it has since been metamorphosed. The following classification of the Indian salt is now proposed:—

(4) the Khewra zone,
(3) the Warcha zone,
(2) the Kalabagh zone,
(1) the Kohat zone.

The Kohat zone would thus represent the first salt to crystallize out, and would therefore contain calcium sulphate and little or no other salt except sodium chloride, and ferruginous materia. Its difference from the anhydrite zone of Stassfurt may be due, either

to sulphurous springs in the original salt lake, or to the presence of sulphuretted hydrogen introduced in some other way—how, does not affect the present question—, the ferruginous material present being converted into sulphide of iron, which would colour the salt mud grey instead of red. It is further assumed that the sulphuretted hydrogen period ceased before the accumulation of the Kalabagh salt, since it and the Warcha and Khewra salt are red. Whether any representative of the carnallite zone of Bischof is present in the Salt Range or not, it is impossible to say. It may be that it is represented in part by some of the Khewra salt, or it may be that the overthrust has everywhere removed it. With the knowledge at our disposal at present it is impossible to offer a decided opinion.

Neglecting, for a moment, the foliation of the salt, the suggested general arrangement of the deposits is approximately that shown in the following section :—



Above the salt comes the secondary gypsum that has formed along the line of the overthrust and represents that line approximately ; and above this are the various geological formations.

The Salt Marl of the Punjab may be composed of comminated material resulting from the overthurst and thus be comparable with the ground moraine or till that forms below an ice-sheet ; and if so it possibly consists largely of original salt-lake and desert material. Its absence in the Kohat area may be explained by the amount of overthrust being greater there than in the Salt Range. If, as seems possible, the Purple Sandstone represents some of the desert deposits that surrounded the drying up, or dried up, salt-lake, and consequently is contemporaneous with, or just younger than, the salt itself, the actual overthrust in the east of the salt area, such as at Khewra, need not be very great.

It is further assumed that the gypsum is a contact product between the salt and the overthrust calcareous formations ; and

although the Khewra and Warcha zones of the salt do not contain much sulphide of iron, the presence of grey salt of the Kohat zone in both the Warcha and Khewra mines, owing to subsidiary overthrusting, enables me to suggest that sufficient sulphide of iron was incorporated in the Salt Marl during the overthrusting, to result in the formation of gypsum in the latter.

If the above assumption is correct, it follows that the gypsum masks the overthrust, and that had it not been for the secondary formation of that mineral, the brecciated junction with the overlying rocks, the complicated fractures, and the masses of foreign rock caught up in the overthrust—such as the alum shales, the bituminous shales, the dolomite, the green clays, the Khewra trap, and all the various isolated, and, what might well be called "erratic," fragments of other geological formations now incorporated in the gypsum, would have made the overthrust strikingly evident at once.

I have neglected the foliation of the salt in the discussion of the present general arrangement of the salt zones, since what I regard as foliation has no relationship to the arrangement of the zones, and only produces a false impression of stratification. The general run of the Salt Range, and the salt-bearing ranges in Kohat, is east—west. The general strike of the salt, except in subsidiary puckers and folds, such as are found in the Nilawan ravine, ranges between E.N.E.—W.S.W. and N.E.—S.W. and the dip between N.N.W. and N.W.; this is opposite to the arrangement of the zones shown in the sketch section and described above. From this I infer that the dip and strike of the salt, as now seen, are the dip and strike of foliation planes, and do not necessarily coincide with the dip and strike of the original stratified beds and zones. Hitherto it has been customary to regard the salt bands as normal stratified beds, a view which was unquestioned by Wynne, and was definitely adopted by him. I now suggest on the other hand that the existing dip and strike of the salt bands is not stratification, but is foliation in a different and opposite direction, due to the original stratified deposits having been sheared or having flowed in a plastic state in a direction oblique to the original stratification planes, and thus become converted into foliated material having its foliation planes in a new and different direction. If this view is correct, and if the present dip has in general no relationship to the original

bedding-planes but is usually in a different direction, its bearing on prospecting operations for potash will be of great importance, since inferences based on the assumption that the banding corresponds to stratification would inevitably lead to wrong conclusions.[1]

The Kohat zone being the lowest, it would appear that the salt deposits should end not very far west of Bahadur Khel, and that the salt is not likely to extend far into Waziristan.[2]

In the foregoing pages I have recorded the facts observable at the present day, and from them I have deduced what appears to me to be their logical outcome. I have also shown how these deductions fit in with and offer an explanation of the various existing characteristics of the salt formation and the gypsum taken as a whole. They seem to me to lead up to a simpler explanation than any yet put forward and the manner in which they account for many observed phenomena that hitherto have been distinctly puzzling gives them a high probability of being correct. It is worthy of note too that deductions based on entirely different observations lead to the same conclusion. Thus the nature of the banding of the salt, its frequent lenticular arrangement, the occasional striking appearance of flow structure in it, and the nature of the salt marl bands led me to infer that the originally stratified beds of salt had subsequently been subjected to flow and that the direction of movement had not coincided with the direction of the original bedding.

The occurrence of marl particles as isolated fragments scattered through the Bahadur Khel salt schist instead of as continuous bands, seems to make this inference inevitable. Furthermore, if the salt was originally a stratified deposit, it must, presumably, have been arranged in zones and was not uniform in composition from bottom to top. The charateristics of the different existing

[1] It is no doubt possible that in certain places the direction of flow or foliation may coincide with the original stratification. If the salt strata were folded at all before the foliation occurred, then places must almost certainly have existed where the two were coincident. But these places would be few, and have not yet been observed; hence on general grounds the possibility is ignored in this report.

[2] Judging from the reports of the trans-border people it seems probable that salt exposures do not exist west of Bahadur Khel in the trans-frontier country, and it is interesting to note that deductions based on the arrangement of the salt zones agree with this information.

exposures are consistent with this view, and, assuming it to be correct, the following zones are suggested as occurring in the Indian salt, in ascending order :—(1) the Kohat zone, (2) the Kalabagh zone, (3) the Warcha zone and (4) the Nurpur and Khewra zone. These salt zones are thus arranged as if they had a dip containing an easterly component. Now the general dip of the present banding (which I regard as foliation) is N.W. to N.N.W., or in the opposite direction to the suggested arrangement of the zones which must of course have coincided originally with the stratification. These two different lines of reasoning, therefore, both lead to the same conclusion, and suggest an hypothesis by which to explain the undoubted irregularity in thickness and composition, and the lenticular and discontinuous character of the potash bands. Another instance of the way in which these deductions mutually support one another is afforded by the gypsum. This, as has been shown by Wynne, overlies the salt. From what I have seen taking place on the Bahadur Khel salt-field and especially along the line of fault on its south-western extremity, and from the nature and characteristics of the gypsum itself, I have inferred that the gypsum may be a contact mineral formed at the junction of the salt with neighbouring formations. If the salt was originally a stratified deposit and arranged in zones, then the gypsum, if also part of this stratified formation, would occupy a definite position in the vertical scale. We find, however, that this is not the case, but that it lies indiscriminately on the Kohat, the Kalabagh, the Warcha and Khewra zones, and this leads to the inference that it has come into its present position after the salt was arranged in its present form and position. It seems impossible, by any conceivable process of folding or overfolding, to account for its present unconformity with the salt zones and frequently with the banding in the salt. If it were a sedimentary deposit one would expect to find it below the salt, since it should have come out of solution earlier than the salt; whereas, if it is a contact mineral, we should expect to find it just where it now occurs.

V.—ECONOMIC RESULTS OF THE HYPOTHESIS.

Khewra.

If the deductions drawn by me in the foregoing pages are correct, it follows that the salt exposed in the Khewra mine belongs to the Khewra zone and should be underlain normally by the Warcha zone, followed in turn, in

descending order, by the Kalabagh and Kohat zones. The presence of the Warcha zone, however, is doubtful. Near the bottom of the deep exploratory drift in No. 12 Pharwala, is a subsidiary overthrust, marked by a fault-breccia, and below this is grey salt resembling that of the Kohat zone. It is possible therefore that the Warcha and Kalabagh zones with their included potash foliæ and lenticles, are cut out by a subsidiary overthrust under the Khewra zone. The Kohat zone contains no potash, and therefore prospecting for potash below the salt exposed in the Khewra mine is not likely to succeed; the subsidiary overthrust may have cut out the Warcha zone altogether and brought the Khewra zone directly on to the Kohat zone, or still more disturbance may have occurred below, and some salt of the Warcha zone may be present. There are, however, no indications that the latter is the case. It has already been pointed out in the preceding paper that if further prospecting is attempted at Khewra, the best course would be to put a boring down at the northern end of the Khewra glen, and so cut through more bands of the salt than are opened up in the Mayo mine. Whether the suggestions put forward in the foregoing pages are right or wrong, it has been amply demonstrated by actual experience that a certain amount of potash will, as already stated in my preceding paper (*supra*, p. 52), occur as irregular lenticular bands in the salt of Khewra and Warcha. These bands will be discontinuous and, almost certainly, very variable in width and composition throughout their length, and will not all lie on the same foliation plane; hence a boring put down through the salt at any particular point will miss certain lenticles. Whether the salt under the northern end of the Khewra glen is foliated material derived from an originally higher zone in the deposits than that which went to form the foliated salt exposed in the Mayo mine, or whether the opposite is the case, there is no evidence at our disposal to show; but it seems probable that it is from a different zone, and that a boring put down through it either to the grey salt or right through the deposit, is likely to pass through potash foliæ that are not seen in the Mayo mine.

Warcha.

As in the case of Khewra, a boring might also with advantage be put down through the salt deposits at the northern end of the Warcha glen, close to the northern guard-post, and on the western side of the glen. This would pass through a considerable thickness of foliated salt

not seen in the mine, and might possibly pass through part of the Khewra zone. Nothing can be deduced, in this connection from the dip of the foliation planes, but investigation would be interesting and should yield lenticles of potash. The same disadvantage exists here as at Khewra, and indeed throughout the Salt Range, that the lenticles of potash are discontinuous and many may be missed owing to the boring passing just outside their limits.

Kalabagh.

No seams of potash were found at Kalabagh, though it was detected both in dripping water and in water lying in the quarries.

The Kalabagh salt seems to be transitional between that of the Kohat zone and of the Warcha zone; potash is not likely to occur in it in any quantity, and for this reason further search here does not seem to offer any prospect of success.

Nandrakka.

This salt is the grey variety of the Kohat zone, with a few bands of pink salt interfoliated with it. It probably represents the top of the Kohat zone and a lower horizon than that of the Kalabagh salt.

Kohat.

Except at Nandrakka, no traces of potash have been detected in Kohat. Owing to the fact that the salt of the Kohat zone was presumably the first to crystallize out of the evaporating saline solution, it is unlikely that any valuable potash seams ever existed in it; and if as now suggested, it has been subsequently sheared across its bedding-planes and converted into a foliated rock sometimes comparable in texture with a schist, the presence in it of potash of commercial value is improbable; but if potash does occur, it will be found only in minute and isolated fragments scattered through, and forming an intergral part of, the schist, a mode of occurrence which would render it valueless commercially.

The Salt Range as a whole.

If the hypotheses put forward in this paper are correct, the highest salt zones exposed along the southern scarp of the Salt Range will be found at the eastern end of the range, and the lowest zones in the western portions of the Kohat Range; it is therefore, advisable to prospect for potash in the eastern portion of the Salt Range. Speaking broadly, the further prospecting is carried towards the east, the greater the probability of finding the higher salt zones. The salt exposed at Khewra and Nurpur seems, before foliation, to have belonged to a

zone corresponding to the kieserite, and possibly to the lower portion of the carnallite, zone of Stassfurt. It is possible that, to the east of Khewra, there may be salt belonging originally to a still higher horizon than that seen at Khewra. It is doubtful, however, whether this is worth investigating. The section around Chambal (33° 20′: 73° 29′) consists, according to Wynne, of faulted and steeply dipping rocks, and it would, therefore, seem preferable to bore near Khewra, where the salt is less tilted. A boring at the head (north) of the Khewra glen through the Salt Marl and right through the salt formation would be exceedingly instructive. If it were intended merely to prospect for potash, the boring could be stopped on reaching the grey salt of the Kohat zone. It seems certain that subsidiary overthrusting has occurred in the salt itself and improbable, therefore, that the whole section of salt would be met with, but this is likely to be the case everywhere throughout the range. The advantage of prospecting near Khewra is that here is perhaps the most easterly gently-dipping salt of the range, or sufficiently nearly so to make it the most suitable spot, owing to its proximity to the railway and to the mining village. Another place where a boring might be put down with advantage is at the northern extremity of the Warcha glen, opposite to the northern guard-post and on the western side of the glen. The salt of the eastern side seems to be more disturbed and the western side is therefore the more suitable. Although the dip of the foliation planes in the salt at Warcha would indicate that higher foliæ are exposed at the head of the glen than near its mouth, it by no means follows that the original salt zone, from which the salt seen at the head of the glen is derived, is a higher zone than that to which the foliated salt seen in the Warcha mine belongs, but it is probably a different zone, and a boring at the head of the glen would probably pass through more salt than one at the mouth of the glen. There is no evidence that salt corresponding to that of Warcha will be met with in the Khewra boring just advocated, and it therefore seems desirable that both should be undertaken. In either case potash is not likely to be met with after the grey salt of the Kohat zone is reached, although the continuation of the boring right through the salt formation would be of great scientific interest.

I have already pointed out the possibility of the bore-holes passing near to, but just outside, potash lenticles, and thus giving no indication of their presence ; this, unfortunately, cannot be avoided,

and is one of the disadvantages consequent on the foliation of the salt. Although I have been able to suggest a rough idea of the arrangement of the original salt zones in an east-west direction, I have no data which will enable me to do so in a north-south direction, and in this connection I would again lay stress on the suggestion that the foliation planes are not the original bedding-planes and have no connection with them, and that if they be regarded as such, any deductions drawn therefrom will be based on a false hypothesis and consequently misleading.

As already stated in the preceding paper, it is not probable that any continuous bed of potash will be found either in the Salt Range or in Kohat. If the salt has been foliated as now suggested, the potash salts will have been re-arranged in discontinuous and irregular lenticles. Where the foliation is of the nature of banding, bands of potash may persist for some little distance, but even then they will probably thicken and thin throughout their length; for if the salt, with its potash, was originally deposited in stratified beds which have been sheared across their bedding-planes obliquely, and the whole converted into a foliated rock, it is improbable that any continuous thick bands or foliæ of potash will be found in the present salt, although a band or lenticle may thicken out abruptly here and there. The prospects of obtaining potash from the salt of the Salt Range are not promising, and the Indian deposits, having been foliated, are at a great disadvantage as compared with the stratified deposits of Stassfurt, where the presence of potash, once known at any point, can be predicted over large areas with tolerable certainty, both as regards position and thickness. In the Indian foliated salt, it is like looking for a needle in a bundle of hay; beyond the fact that the Kohat zone does not contain potash in detectable quantities, no assertion can be made as to where a lenticle of potash will occur, or as to its dimensions or shape when located.

LOCALITY INDEX.

Bahadur Khel	33° 10,′	71° 0′.
Banda Daud Shah	33° 17′,	71° 11′.
Chambal	33° 20′,	73° 29′
Chishanna Ghanda	33° 22′,	71° 36′.
Ganjalli	33° 25′,	71° 46′.
Guruza	33° 7′,	71° 2′.
Jatta Ismail Khel	33° 18′,	71° 17′.
Kacho	33° 6′,	71° 33′.
Kalabagh	33° 58′,	71° 33′.
Karak	33° 7′,	71° 9′.
Khewra	32° 33′,	73° 4′.
Kurar	33° 13′,	71° 20′.
Malgin	33° 18′,	71° 31′.
Mari	32° 58′,	71° 35′
Nandrakka	33° 15′,	71° 33′.
Nilawan Ravine	32° 34,′	72° 38′.
Nurpur	32° 39′,	72° 36′.
Shahidan	33° 12′,	71° 16′.
Speena (Spina)	33° 13′,	71° 16′.
Vasnal	32° 43′,	72° 33′.
Warcha	32° 25′,	71° 58

LIST OF PLATES.



FIG. 1. BAHADUR KHEL SALT SHOWING SCHISTOSE STRUCTURE.

(Natural size.)



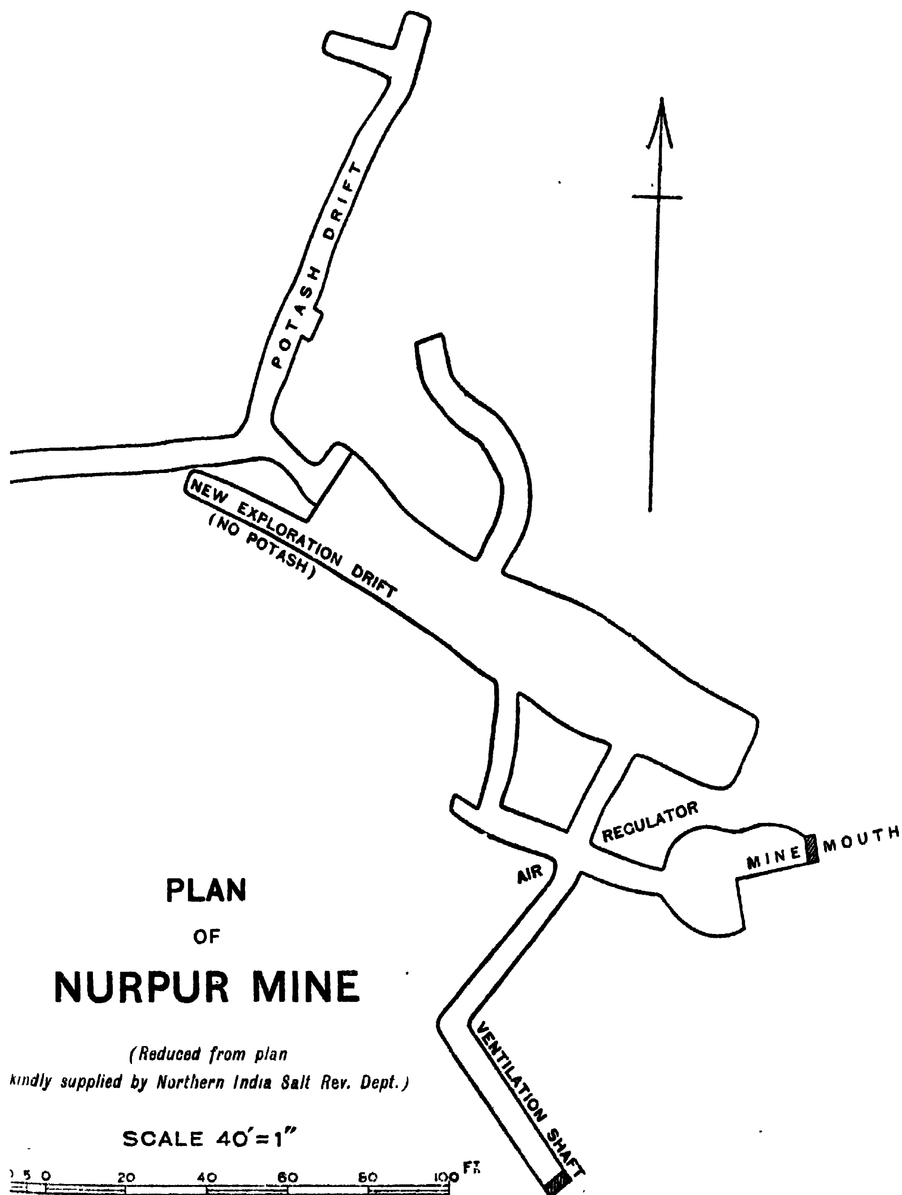
Photographs by Murray Stuart.

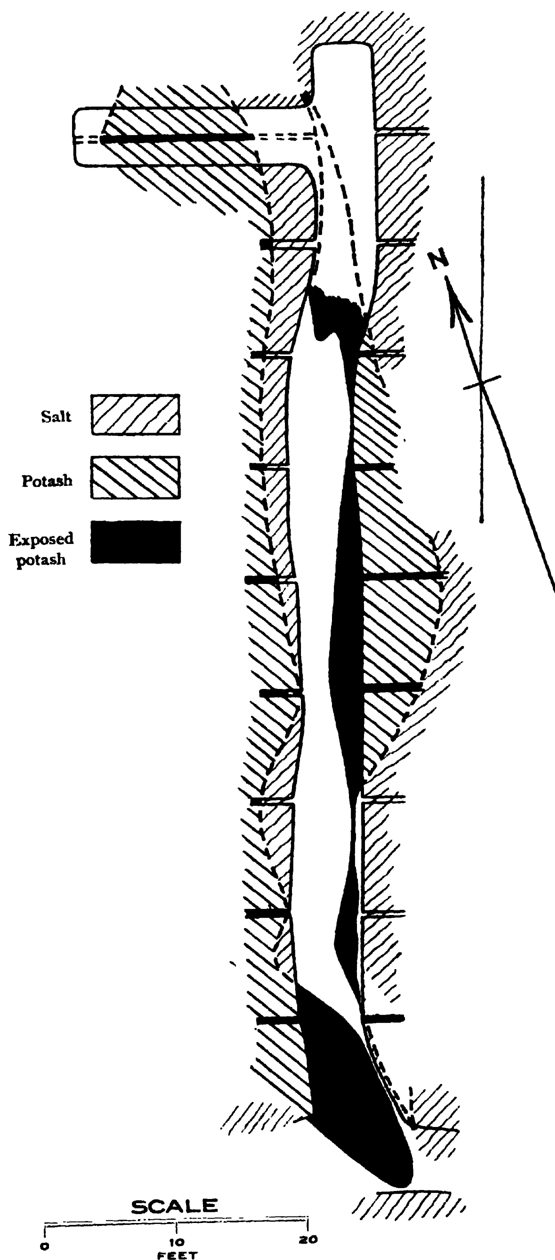
FIG. 2. A SALT QUARRY AT BAHADUR KHEL



Photograph by Murray Stuart. *G. S. I. Calcutta.*

THE SCHISTOSITY OF BAHADUR KHEL SALT


POTASH DRIFT
NEW EXPLORATION DRIFT
(NO POTASH)
REGULATOR
MINE MOUTH
AIR
VENTILATION SHAFT
PLAN
OF
NURPUR MINE
(Reduced from plan
kindly supplied by Northern India Salt Rev. Dept.)
SCALE 40′=1″
5 0 20 40 60 80 100 FT.



Sketch by Murray Stuart.

G. S. I. Calcutta.

PLAN OF THE POTASH DRIFT, NURPUR MINE,

(Showing test holes drilled into the walls, and the potash bands.)



FIG 1. FORMATION OF CRYSTALS OF SELENITE ON THE SURFACE OF GREY CLAY. BAHADUR KHEL SALT-FIELD.



Photographs by Murray Stuart. G. Calcutta.

FIG. 2. STAGES IN THE FORMATION OF ROCK GYPSUM.

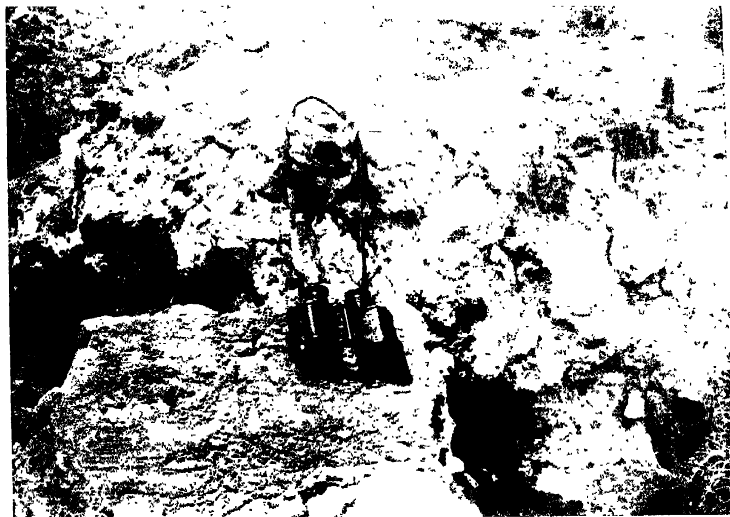
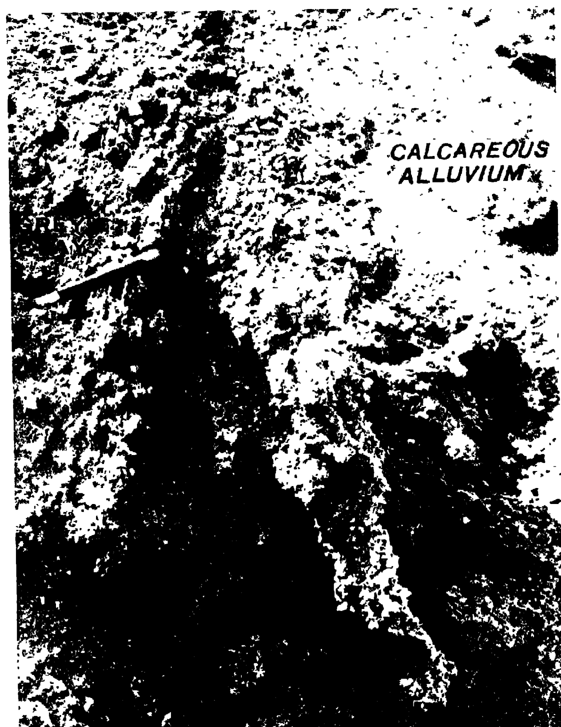
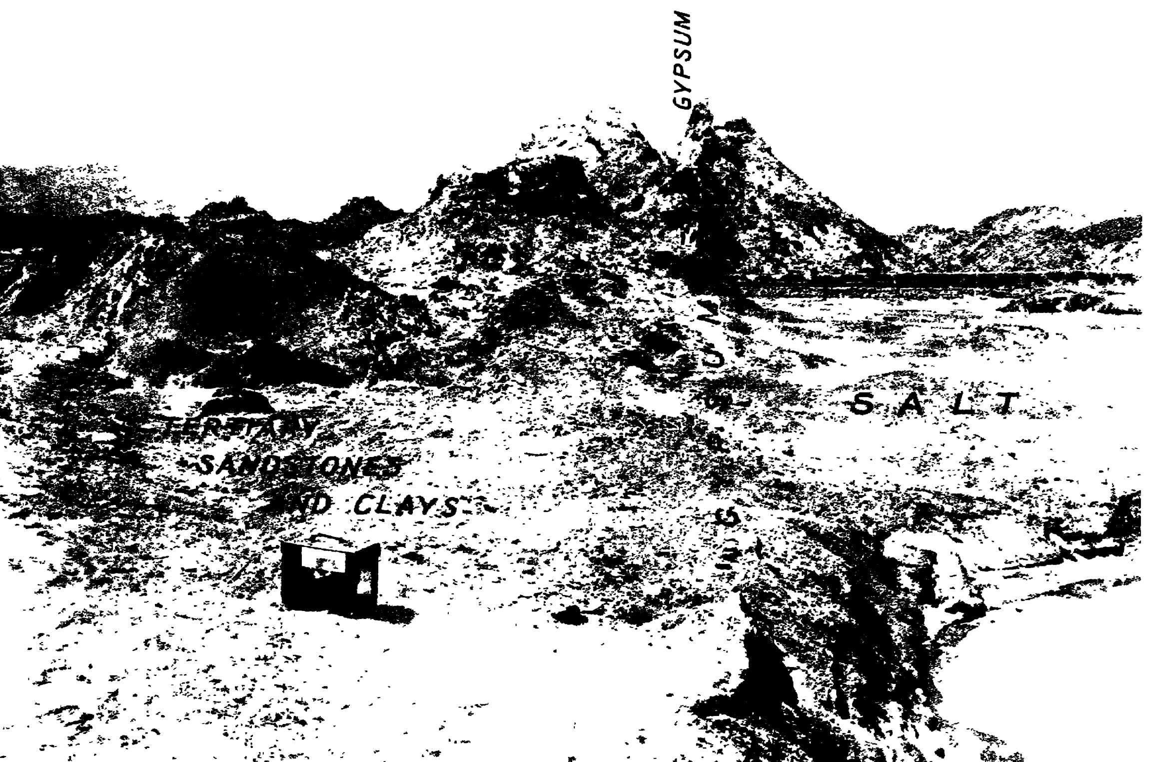


FIG. 1. GYPSUM CRUST COATING LIMESTONE BOULDER.



Photographs by Murray Stuart. *G. S. I. Calcutta*

FIG. 2. FORMATION OF A MODERN CLIFF OF GYPSUM, IN MINIATURE.



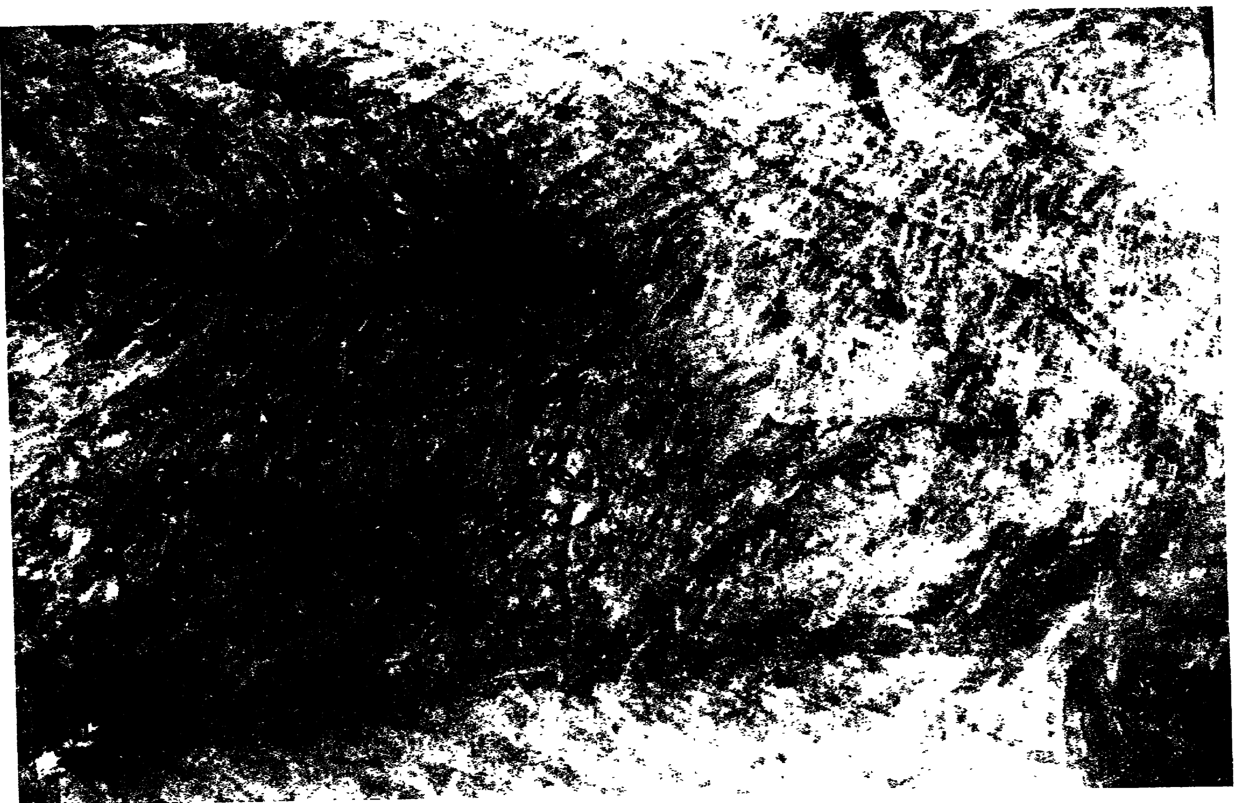
Photograph by Murray Stuart. *G. S. I. Calcutta.*

FORMATION OF GYPSUM ALONG THE LINE OF THE FAULT AT THE SOUTH-WEST BOUNDARY OF THE BAHADUR KHEL SALT-FIELD



G. S. I. Calcutta

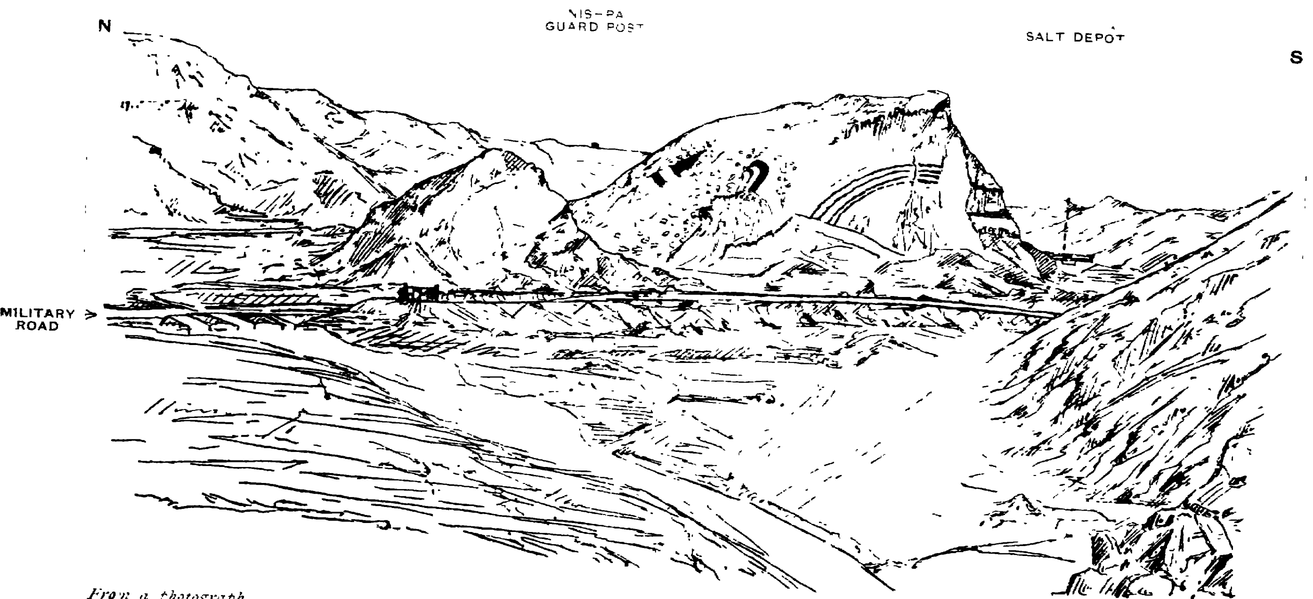
FORMATION OF A MODERN SHEET OF GYPSUM (G) OVER BAHADUR KHEL SALT.



Photograph by Murray Stuart. G. S. I. Calcutta.

OVERFOLDING AND PUCKERING OF GREY SALT BELOW THE OVERTHRUST IN THE WARCHA SALT MINE. ([illegible] Natural size)

(G, G, are brecciated fragments of gypsum from the fault breccia.)



From a photograph.

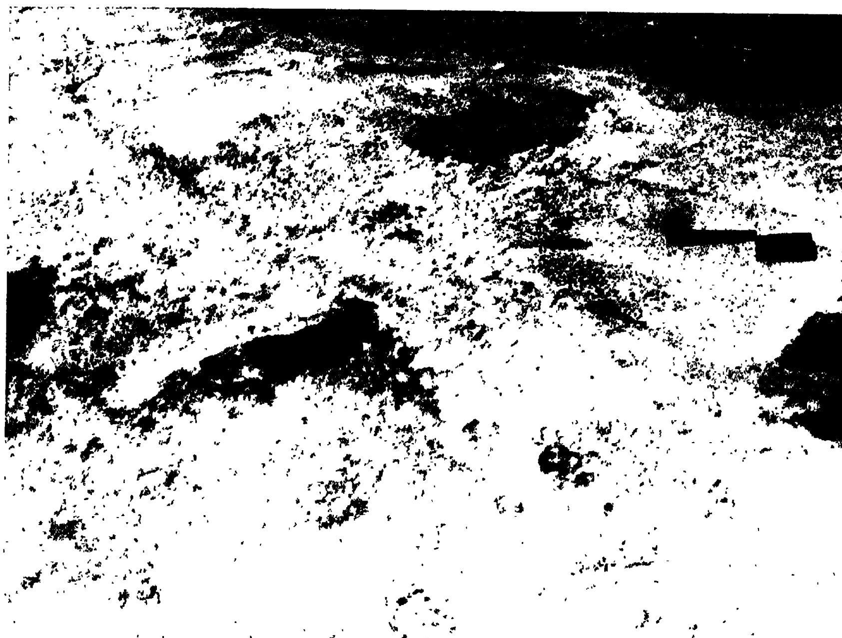
G. S. I. Calcutta.

SKETCH SHOWING FOLDING IN THE WESTERN FACE OF THE WESTERN SALT HILL, BAHADUR KHEL.



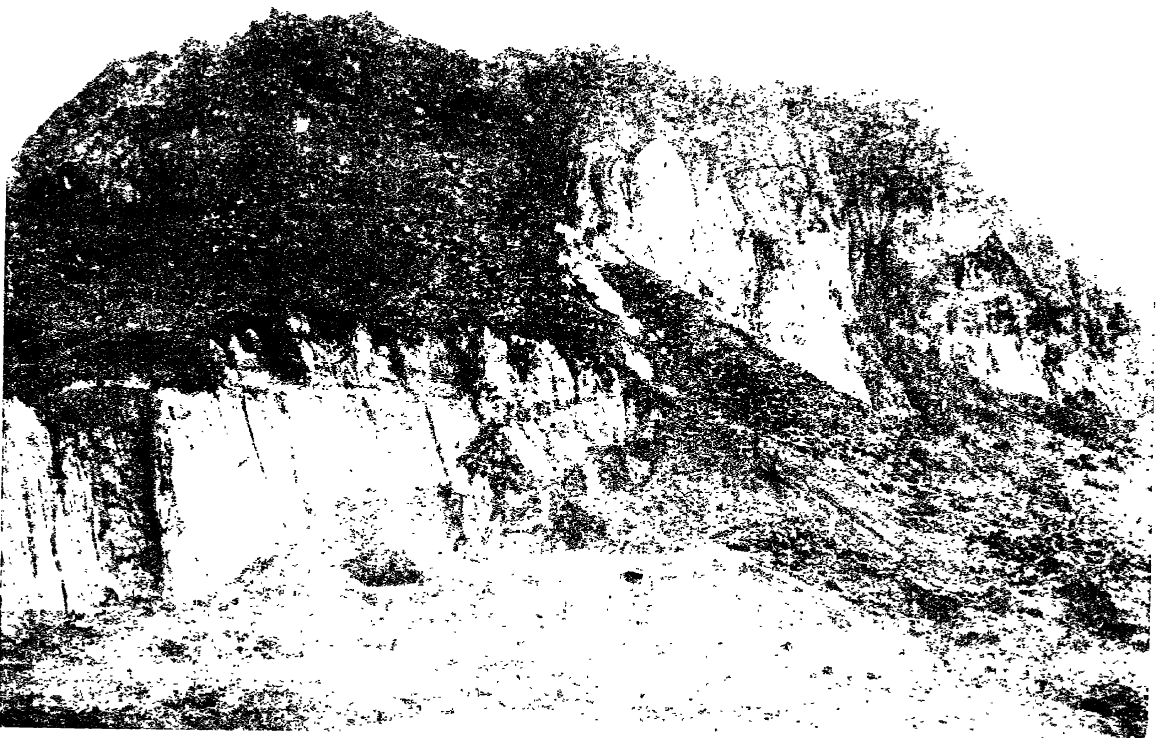


FIG. 1. WESTERN FACE OF THE WESTERN SALT HILL, BAHADUR KHEL Showing folding



Photographs by Murray Stuart. *G. S. I. Calcutta.*

FIG. 2. SULPHATE OF SODA BREAKING THROUGH SALT CRUST.



Photograph by Murray Stuart.

G. S. I. Calcutta.

NORTH-EAST CORNER OF THE WESTERN SALT HILL BAHADUR KHEL



FLOW STRUCTURE EXHIBITED BY THE POTASH AND MAGNESIA BANDS (P), IN CHAMBER No. 3 OF THE WARCHA SALT MINE.



Photograph by Murray Stuart. G. S. I. Calcutta.

THE MAIN MARL BAND OF THE WARCHA MINE

Showing thickening and thinning of the included magnesia band. (Chamber No. 4)

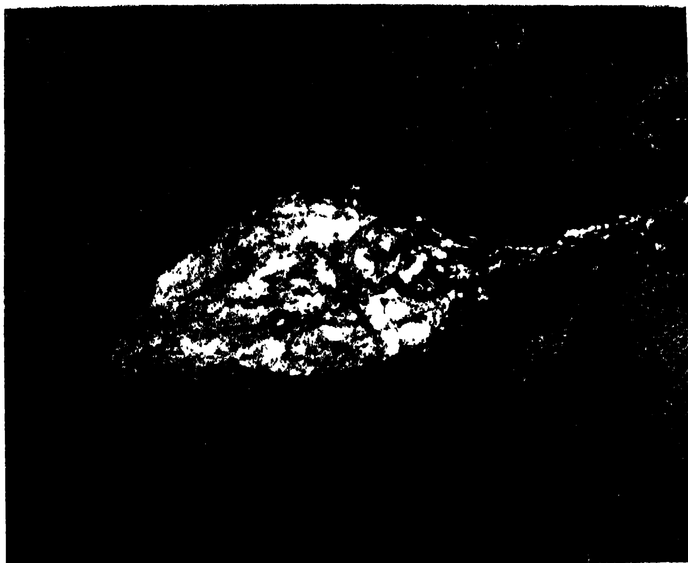


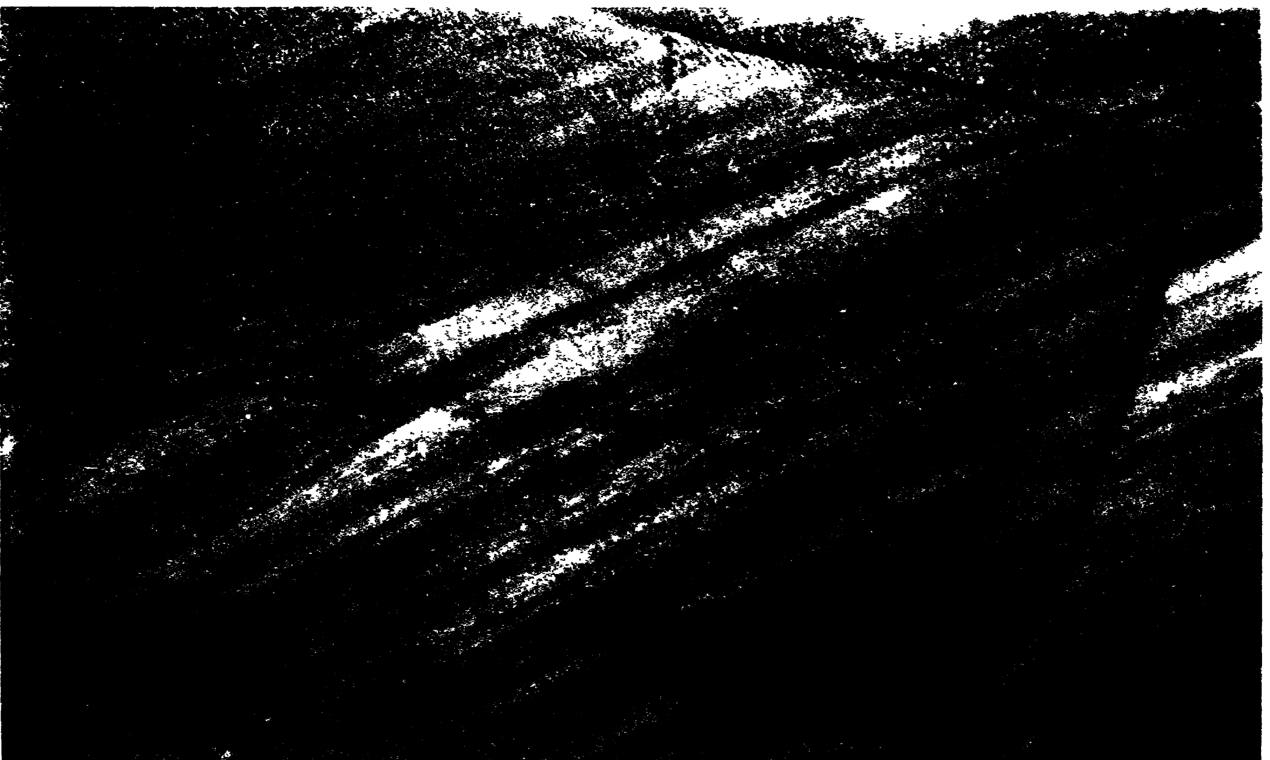
FIG. 1. AUGEN-SHAPED LENTICLE OF MAGNESIA SALT, 4 FEET THICK, IN THE MAIN MARL BAND OF THE WARCHA SALT MINE.



Photographs by Murray Stuart. *G. S. I. Calcutta.*

FIG. 2. FLOW STRUCTURE EXHIBITED BY THE SALT AT KHEWRA.

(*$\frac{1}{12}$ Natural size.*)



Photograph by Murray Stuart. *G. S. I. Calcutta.*

WELL BANDED KHEWRA SALT, showing lenticular nature. ($\frac{1}{5}$ natural size).



Photograph by Murray Stuart. *G. S. I. Calcutta.*

LENTICLES OF SALT OUTLINED NATURALLY BY MARL BANDS, IN THE NEW LOWER TUNNEL, KHEWRA SALT MINE.



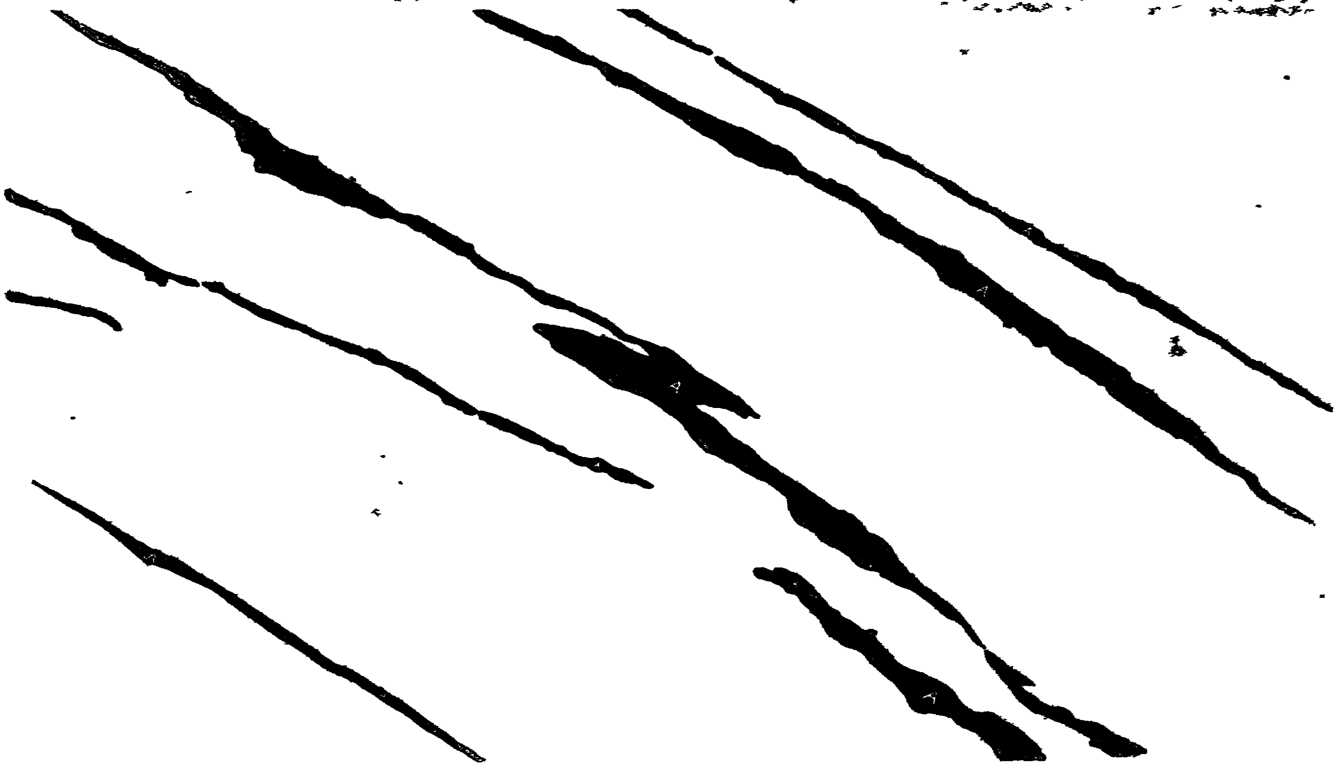
G. S. I. Calcutta.

PATCHES OF SULPHATE OF SODA ON ALLUVIUM, BAHADUR KHEL SALT-FIELD.

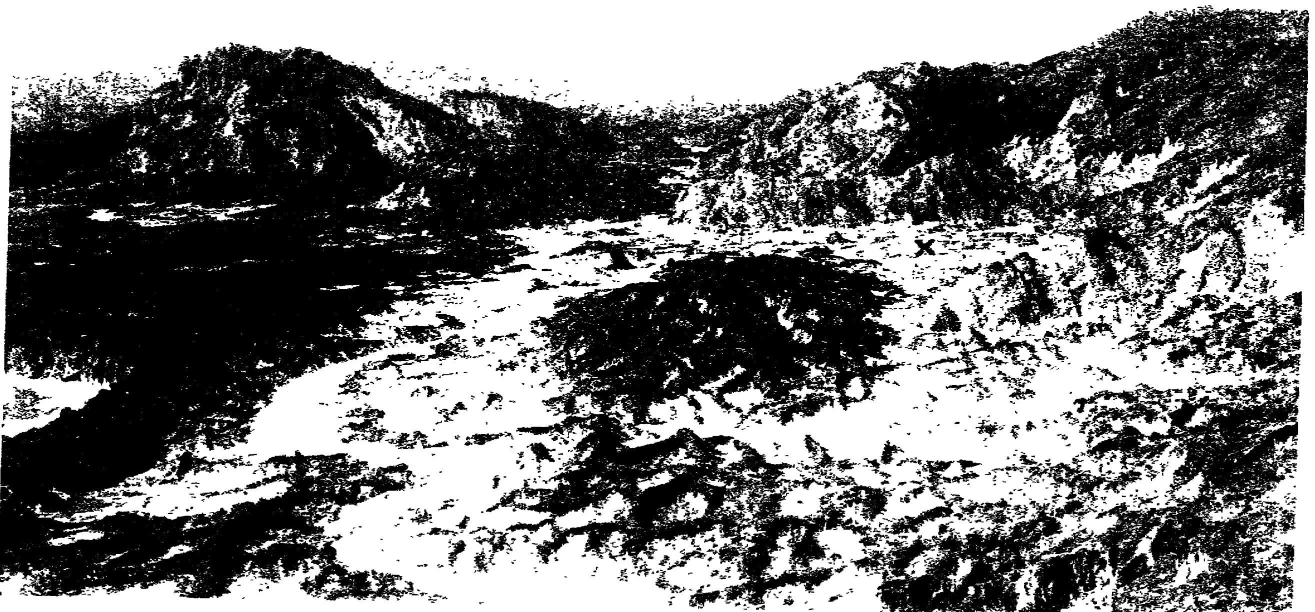


Photograph by Murray Stuart. *G. S. I. Calcutta.*

BANDS OF MARL IN KHEWRA SALT (½ Natural size) Showing clearly that structure is not ordinary stratification



A = MARL BANDS



THE WESTERN END OF THE BAHADUR KHEL SALT-FIELD.

as seen westwards from the Nishpa guard-post, showing the two salt hills in the left middle distance, and the rectangular fracturing of the salt shown up by the clay bands and alluvium which occupy the cracks. Two men are seen taking samples of salt, immediately below the X.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1919. [July.

THE DISTRIBUTION OF ORES OF TUNGSTEN AND TIN IN BURMA. BY J. COGGIN BROWN, O.B.E., M.Sc., F.G.S., AND A. M. HERON, B.Sc., F.G.S., *Assistant Superintendents, Geological Survey of India.* (With Plates 26 and 27.)[1]

SINCE the commencement of the war the demand for tungsten has resulted in an increased exploitation of the wolfram deposits of Burma, and in extended prospecting for new occurrences of the same mineral. Cassiterite is intimately associated with wolfram and as a consequence has shared in the same activity.

No previous attempt has been made to summarise the information available concerning the deposits of tungsten and tin ores in Burma or to trace their distribution from one district to the next, and we are of the opinion that the time has come when this should be done. We propose to limit our observations strictly to geological and mineralogical data and to give a general idea of the situations, salient characteristics and mineral associations of the wolfram and cassiterite lodes. We hope that these notes will prove helpful to the mining industry and at the same time be useful to geologists who need facts on which to base their speculations on the origin of these ores.

Almost every occurrence which is described has been examined by one or both of us and where this is not the case it is mentioned.

[1] Read at the Indian Science Congress, Bombay, January 1919.

The descriptions represent the state of our knowledge to-day and are given without prejudicing the interpretation of new phenomena, which will doubtless come to light as deeper mining progresses.

We have to point out that when the general lode trend on any particular mine is indicated, it represents the average strike of the lodes now being exploited, and in most cases examples could probably be found departing to a greater or lesser degree from it.

Two maps are attached. The first (Plate 26) shows the locations of the more important wolfram and cassiterite deposits in Burma, which stretch from Byingyi in Yamethin district in the north to Maliwun in Mergui in the extreme south, a total length of approximately 720 miles. The other (Plate 27) is a small-scale reduction of part of the geological map of Tavoy district illustrating the approximate positions of the more important mines in it and their close association with the granite intrusions.

Yamethin District.

Byingyi.

The wolfram-bearing area is situated close to the summit of the peak Byingyi, 6,254 feet above the sea, on the borders of the Yamethin district and Loi Long State, Southern Shan States. This occurrence is the most recently discovered in Burma, and, so far as prospecting up to date goes, appears to be of small extent, though the lodes are numerous and carry good values. Several Rangoon firms have taken up areas, but so far output has been practically confined to the original concession belonging to Messrs. B. M. Karwar.

The lodes are all in granite, of the same type as that of Tavoy and Mergui, and crop out below the small capping of black calcareous grit which forms the summit of Byingyi, and into which the granite is intrusive.

The lodes have not yet been opened up, but so far as can be seen have a general N.W.-S.E. strike, and dip S.W., some at comparatively low angles. None were seen of more than 15 inches in thickness. Beryl is a common mineral in them, and has not been recorded elsewhere in Burma as an associate of wolfram. Molybdenite is constantly present and appears to occur in greater amount in the higher lodes than in those lower down the hill. Cassiterite was not seen, nor sulphide minerals, but the apparent

absence of the latter may be due to oxidised outcrops only being available for observation.

Bawlake State, Karenni.

Mawchi.

This well-known mine is situated in the southern portion of Bawlake State, Karenni. It has not been examined by either of us. There are at least ten important lodes varying from 2½ to 5 feet in thickness. The general strike is N.N.E.-W.S.W. and the dip either vertical or at high angles to the W.N.W. All the lodes are in granite and the capping of the granite hill in which they occur is composed of limestone. The veinstuff in all the lodes is drusy and carries cassiterite, wolfram, arsenical pyrites, pyrite, chalcopyrite and black tourmaline. Cassiterite and wolfram occur as intimate mixtures and also separately. The country enclosed by the lease is deeply dissected and varies from 1,400 to 4,000 feet above the level of the sea. The lodes are worked by modern methods and successful exploration has been carried out to a greater depth than on any other deposit of the same kind in Burma. The concentrates are recovered by an up-to-date mill.

Amherst (Moulmein) District.

Ye.

Specimens of wolfram have been procured from the neighbourhood of Ye, near the boundary between the Tavoy and Amherst districts, and it is also said to occur in the Dorna range, on the Siam frontier, but no exploitation has taken place.

Belugyun Island and the Seludaung Range.

Alluvial cassiterite has been worked in three localities, (1) Belugyun Island at the mouth of the Salween River and (2) and (3) to the west and east respectively of the Seludaung range, which divides the coastal plain of the Amherst district from the valley of the Winyaw, a tributary of the Ataran. At (1) the deposits are on the lower slopes of the ridges of argillaceous quartzite and grey slate, which form the backbone of the island. These rocks are penetrated by veins of (*a*) coarse pegmatite consisting of quartz, felspar and tourmaline, with a little muscovite and garnet, (*b*) fine-grained and foliated tourmaline-granite and

(*c*) drusy white quartz. The tinstone may come from any or all of these, but has not been discovered in them. In the concentrate obtained by panning the alluvium, tourmaline (in large quantity), garnet and ilmenite are present with the cassiterite. The deposits have not proved profitable when worked by tribute methods.

Sakangyi.

A number of concessions have been taken out around Sakangyi village, on low country made up of quartzitic sandstones and argillites, underlain by intrusive granite. The concession worked by the Amherst Tin Mining Company at Mawpalaw hill produced 11 tons of ore during May 1918, but this region has not been visited since some time before work started.

Paya and Hlutsha.

Several concessions lie near Paya and Hlutsha, to the S.S.E. of Seludaung G. T. S. Alluvial cassiterite in small amount was seen on Mrs. Hla Aung's and Messrs. J. W. Darwood and Company's areas. Some years ago two concessions were taken out a few miles to the south by the Hon. Lim Chin Tsong and Dr. Sisman, but were allowed to lapse.

Thaton District.

Central Range.

The Thaton cassiterite and wolfram areas are all situated on the long ridge which runs parallel to the railway from Pegu to Martaban, the railway station for Moulmein.

The wolfram-bearing lodes are in two well marked series, one in granite, the other in quartzitic sandstones, argillites and grits.

The granite forms the high hill on which is the Zingyeik pagoda, and differs from that of Tavoy and Mergui in that it bears tourmaline as an accessory mineral and has a marked foliation and jointing running in a N.W.-S.E. direction; the lodes lie parallel to this jointing, dipping N.E. They differ markedly from those of Tavoy, for in them tourmaline is always present, with quartz, muscovite, and probably felspar, and they are thus pegmatites. As well as wolfram they carry pyrite, chalcopyrite, arsenopyrite and molybdenite.

There are four lodes, close together, of an average thickness of four inches, and they can be traced for the unusually long distance of 2½ miles. Beyond their southern termination are two

others rather thicker, dipping in the opposite direction and more irregular in strike. The lodes in the sedimentaries are some distance to the east of the granite, in much lower country. They dip to the west at comparatively low angles and are thicker but much less continuous than those in the granite; they are of the normal Tavoy type in which quartz and wolfram are the chief vein materials.

All the Thaton concessions are small producers, but work with the advantages of cheap labour and close proximity to the railway line.

The two tin concessions are at the extreme ends of the line of wolfram-bearing areas. That to the north (Kadeik) belonging to the Hon. Lim Chin Tsong is a small but rich alluvial area on which a gravel pump on a barge has recently been erected.

During its first year this concession produced about 90 tons of ore by tribute methods. No cassiterite-bearing lodes have yet been discovered.

The other, worked by Mr. Singleton, is a small patch of eluvial ground in which the cassiterite is derived from small veins and stringers in the underlying sedimentaries.

Tavoy District.

The Tavoy district has an area of 5,308 square miles. The official lists for the year 1917 show that mixed concentrates were exported from 132 concessions. In addition to this 3 concessions exported tin-ore exclusively and 1 concession exported a small quantity of molybdenite only. Again, there were a number of areas under prospecting licenses which are known to contain wolfram-bearing and cassiterite-bearing lodes from which no ore was exported at all.

It is not easy to devise a clean-cut geographical classification for the Tavoy mining field and the most satisfactory method of grouping the mines is with the great masses of intrusive granite with which they are associated. Before attempting to do this it is necessary to point out, in case the figures lead to misconception, that by far the greater number of producing concessions yield only small amounts of concentrate. In 1917, the total production of

the field was 3,653½ tons of mixed concentrates and the following table shows how it was distributed amongst its various sources :—

Production per annum.	Number of mines.	Percentage of production.
Under 5 tons	74	2·8
Over 5 tons and under 10 tons	18	3·2
Over 10 tons and under 50 tons	25	16·0
Over 50 tons and under 100 tons	9	17·5
Over 100 tons	6	60·5

The Coastal Range.

The greater part of the Tavoyan coast line is formed by a high granite ridge which rises from the sea a few miles to the north of Ye in the Amherst district. It is breached by the Ye river, crosses the Malwedaung range, forming the northern boundary of the district at an elevation of about 2,800 feet and then continues south. The wolfram mine of Medaw Kanbay is situated on its eastern flank a few miles north of the point where it is breached by the narrow tideway known as the Heinze Basin.

Medaw Kanbay yields a concentrate practically free from tin. It comes from a peculiar flat lode which outcrops at intervals around the peripheries of a group of hillocks and varies in thickness from 1½ to 3 feet. It is often divided horizontally into two or three portions by thin intervening layers of country rock, the argillite of the Mergui series. Granite occurs in the high range to the westward. The mine produced 58 tons of wolfram in 1917. It belongs to U Ni Toe.

The Kanbauk Mines of the Kanbauk (Burma) Wolfram Mines, Limited, lie in a narrow valley in the Mergui sediments filled in with thick alluvial and detrital deposits. The valley, which leads into the main channel of the Heinze Basin from the south, is surrounded on the east, south and west by high granite walls. At Kanbauk proper, the main lode series strikes approximately E. and W. and dips at about 60° to the south. The same directions prevail in the case of a second lode series at Kanbauk West. But

at Thinganyun, a section of the mine to the south of Kanbauk proper, the dip is towards the north at an average angle of 45°, while the strike remains the same. All the lodes are in sedimentary rocks, which are traversed also by a thick basic dyke a short distance to the east of the main lode series.

The concentrates from Kanbauk contain a high proportion of cassiterite, while sulphides of iron, copper, lead and zinc occur in the deeper parts of the lodes; pyrite is very common and the other sulphides are of rarer occurrence. Native bismuth has also been found *in situ*. The lodes are often drusy and this is a very unusual feature in Tavoy. A dark purple fluorite and small quantities of siderite have been noticed in one of the lodes. The alluvial and detrital deposits are of great extent and yield cassiterite, wolfram and oxidised bismuth compounds in profitable quantities. Both the lodes and surface deposits of this mine are worked by the most modern mechanical devices.

Placer deposits of cassiterite occur on the flatter ground near the shores of the Heinze Basin. They are now being systematically tested on Booth's Grant and adjoining areas by Mr. R. Ady.

Four miles west of Kanbauk, and on the eastern flank of the range, is the Taung-shun-taung mine owned by a syndicate composed of Mr. R. Ady and several others. The most noteworthy feature of this mine is the occurrence of flat lodes like that of Medaw Kanbay. The concentrates contain a high percentage of tin-stone.

South of Kanbauk the Coastal Range rises rapidly and attains its maximum elevation in the peak Paungchon Taung, 3.805 feet above the sea. Approximately midway between Kanbauk and this peak are the mines of Kechaung and Pachaung, lying slightly to the east on a narrow spur of sedimentary rocks which wrap over on to the higher slopes of the granite behind. The Kechaung mine belongs to Quah Cheng Guan, and Pachaung is owned by the Wagon-Pachaung Wolfram Mines, Limited. Both mines work on the same lode system and produce a clean wolfram concentrate. The Kechaung strike is generally N. and S., though there are lodes with an E.N.E.-W.S.W. trend.

To the south-east of the Paungchon Taung and between it and Tavoy river, but again on the sedimentary series, is the Egani mine of the Egani Tavoy Mining Company, Limited. The range

continues more or less directly south to Tavoy Point where it disappears under the sea, reappearing in Tavoy Island and other islands of the Mergui Archipelago further south still.

South of Egani no mineral deposits of any economic importance have been located, but wolfram-bearing quartz lodes occur in granite near Thebon and in sediments near Tawshe, both of which places are within a few miles of Tavoy.

The Frontier Range.

The range which divides the Tavoy district from Siam and which rises to heights of over 3,000 feet in the latitude of the Heinze Basin consists of intrusive granite of the ordinary type. A number of concessions have been taken out recently in this region, but up to date only one of them has produced any quantity of ore. This is Messrs. Steel Brothers & Co. Ltd.'s Zimba mine, where several lodes have been discovered in granite near its contact with the sedimentary rocks of the Mergui series. The strike is said to be N. and S., but we have not confirmed this observation, as when the mine was inspected the lodes were buried. The concentrate is practically free from tin and contains small quantities of bismuth compounds. Molybdenite occurs in greisen bands associated with the lodes.

The Bolintaung-Byaukchaung Range.

This is a band of intrusive granite from one to three miles wide which runs in a north-westerly direction for seven miles from the Bolintaung peak before it joins the main Sinbo-Sinma massif. The latter, although one of the largest expanses of granite in the district, does not contain any mines and one of us has already brought forward a theory attempting to account for the absence of ore deposits in it.[1] The Bolintaung range is breached by the Talaingya river. Practically the whole of it is covered with concessions, most of which produce small amounts of ore. The largest mine of the group is Byaukchaung belonging to the Tavoy Concessions Co., Ltd. Most of its output comes from the treatment of surface deposits. The concentrate contains little cassiterite and the wolfram appears to be derived from very numerous thin stringers and greisen bands which penetrate the granite and shed the minerals into the surface material as the rock decomposes. The

[1] J. Coggin Brown, "Economic Geology of Tavoy." Lectures delivered at Tavoy under the auspices of the Mining Advisory Board, Rangoon, Government Press, 1918, p. 68.

strike of the lodes in this range varies from N.W.-S.E. to N.E.-S.W., though the general trend is to the west of north.

The Kalonta mine of the same Company lies on a small granite boss of its own, two miles up the Talaingya chaung from the main intrusion. Here a group of lodes with a N.N.E.-S.S.W. strike is worked. The concentrate carries a little more tin than the Byaukchaung material and it is interesting to note that bismuthinite has been found *in situ*. The granite of this locality, like that of Byaukchaung, has undergone much alteration resulting in the production of greisen.

About 3 miles to the west of the Bolintaung peak, is situated the only important tin mine which the district at present possesses. Working is confined to sluicing the surface deposits, which are 2 or 3 feet thick and overlie decomposed argillites and quartzites of the Mergui series on a steep hill side. These are penetrated in all directions by thin quartz stringers, often of almost microscopic dimensions, but rich in cassiterite. We are inclined to think that the proximity of the Bolintaung granite is not without a bearing on the origin of this ore. The concentrate from the mine does not contain wolfram.

The Kyaukanya-Peneichaung Ridge.

South of Bolintaung the granite disappears under the sedimentary covering, but it comes to the surface again a few miles further south, along the same direction of strike in the Kyaukanya hills and further south again in the Peneichaung hill. There is much mineralisation in both localities, though the amounts of wolfram produced from the lodes are small. At Kyaukanya the main strike is W.N.W.-E.S.E. with a high dip to the N.N.E. The concentrate from the mines on this ridge is particularly high in wolfram and practically tin-free.

About half way between Kyaukanya and Peneichaung the well-known Kadando lode crosses the Maungmeshaung valley close to a small granite exposure in the stream itself. This lode has been traced for several thousands of feet on the surface and varies from 3 to 5 feet and more in width. It contains wolfram with large quantities of pyrite, chalcopyrite, and pyrrhotite, and yields beautiful specimens showing wolfram cut by the two latter sulphides.

A quarry recently opened at Peneichaung on the Pagaye-Hermyingyi road exhibits excellent sections of the granite of this hill.

Wide bands show extensive greisenisation and contain pyrite, chalcopyrite, galena and thin layers of a violet fluorspar. Wolfram-bearing lodes occur at a higher elevation and have given rise to eluvial deposits rich enough to be exploited.

The Pagaye mine of the Rangoon Mining Co., Ltd., which is operated by the Bombay-Burma Trading Corporation, Ltd., is about 3 miles from the Peneichaung granite hill, still in the same line of strike. Here a large number of wolfram-bearing pegmatites and associated quartz lodes strike approximately N. 35° W.-S. 35° E. with a vertical dip, in argillites of the Mergui series. One section of the main lode series exhibits a fine stockwork in which scores of narrow quartz veinlets carrying wolfram and cassiterite are seen. The selvages of these veinlets are bounded by mica walls. Felspar is a very common mineral in the pegmatitic portions of the lodes, which also carry quartz, mica, wolfram, cassiterite, pyrite, chalcopyrite and occasionally small crystals of green and blue fluorite. In the upper portions the chalcopyrite is sometimes coated with thin films of indigo-blue covellite. Small quantities of scheelite are also found at Pagaye and are picked out of the jig concentrates from the mill. This mineral has also been obtained *in situ* in a wolfram-bearing quartz lode of the ordinary type. The detrital deposits of the slopes carry wolfram and tin-ore and an alluvial cassiterite deposit is also exploited.

Hermyingyi.

In the five miles of hilly country built up of rocks of the Mergui series separating the southern edge of the Sinbo-Sinma mass from the northern edge of the Central Range there are at least five separate small granite exposures. The Hermyingyi mine of the Hermyingyi Mining Co., Ltd., is situated on the southernmost of these. The granite itself is indistinguishable from the typical granite of the Central Range which comes to the surface about a mile away. In 1917 Hermyingyi produced 1,051 tons of concentrates out of the district's total of 3,653½ tons. In 1916 the corresponding figures were 765 tons in a total of 3,034 tons. The actual geological conditions, rock compositions and mineral associations of Hermyingyi are much the same as those on the other larger mines in similar situations. The axis of the granite exposure is about 1,500 yards in length, striking approximately N.N.W.-S.S.E. Its greatest breadth is 450 yards, but it narrows to considerably less than this at either end. It is breached by the Maungmeshaung stream

practically at right angles to its axis and divided into two hilly sections separated by its narrow valley. Sedimentary rocks rise high above the granite in Big Hill on the south and Tin Hill on the north. The lodes are found in both the granite and in the sediments. Bands of greisen commonly form borders to them in the first case and often contain relatively large quantities of wolfram and cassiterite. The strikes range in different cases a few degrees on either side of north and south. Other lodes are worked in an isolated patch of granite crossed by the northern boundary line of the lease. Some of the lodes in the main workings have been traced for several hundreds of feet.

The detrital deposits on the slopes of Tin Hill and Big Hill are of great extent and are responsible for much of the output during the rainy season. A short distance below the point where the Maungmeshaung leaves the granite and where its valley broadens out there is another surface deposit consisting in our opinion of talus deposits roughly sorted by water and mingled with true river deposits lower down. This contains wolfram and cassiterite in profitable quantities.

Hermyingyi ore contains a large proportion of cassiterite. In the unweathered portions of the lodes iron pyrites occurs; molybdenite, galena and zinc blende have been noticed; mica is fairly common and small quantities of pale fluorite are sometimes seen.

In the adjoining concession of Hermyingale, a lode has been found which as far as our experience goes is unique up to the present time in Tavoy. It is a thin lode containing molybdenite, pyrite, an altered mica and cassiterite with relatively small amounts of wolfram. It is bordered by a band of rock entirely made up of topaz and colourless fluorite; which in its turn is edged by a greenish-grey mica rock containing fine-grained pink cassiterite and bands of coarsely crystalline mica. The country rock consists of argillites.

We regard the Hermyingyi occurrence as a small granite boss, which has not suffered extensive denudation and is probably connected underground with the main intrusion to the south.

The Central Range.

This intrusion commences as a rounded mass of granite, three-quarters of a mile in diameter about a mile to the S.S.E. of Hermyingyi. Its western boundary runs south for seven miles and then swings round to the S.S.E. The eastern boundary follows approximately the same direction for 12 miles and then turns more to the east. As

a consequence, the width of the granite belt, which is only ½ mile across at its constricted portion, is at least 6 miles, 20 miles further south. The total length of the intrusion is at least 32 miles, so that its average breadth is small in comparison with its length. At its southern extremity the western boundary swings eastwards to meet the eastern one. The intrusion forms the high ridge visible from Tavoy and contains the peaks Pya Taung (3,575 feet), Khat Taung (3,545 feet), Nwalabo (5,063 feet), and the high massif of Southern Paungdaw, which has one peak of 5,133 feet above sea level. Both sides of the intrusion are steep. The western one is precipitous in places. With the exception of Southern Paungdaw, that is to say the portion lying south of Lat. 14° 0′, which is still imperfectly prospected and little known, practically the whole of the intrusion and its surrounding contact zones are covered by grants of ground held under prospecting licenses or mining leases. Especially characteristic of the southern portions are the isolated patches of sedimentary rocks which lie on the upper surface of the granite, forming the last remnants of its former covering, which still resist denudation. The intrusion is breached by the Pauktaing stream and fine sections of the granite are seen in its gorge. This carries the main easterly road and telegraph line connecting Tavoy with Siam.

The northern section of the intrusion contains the Taungpila group of mines, the most important of which is Quah Cheng Guan's Taungpila. It adjoins the corner of the Hermyingyi lease. Taungpila is one of the six mines of the district which produced over 100 tons of mixed concentrates in 1917. The strike of the lode system is to the W. of N. and E. of S. and the dip high to the E.N.E. as a rule. Like its neighbour Hermyingyi, its concentrates contain a high proportion of cassiterite.

North of Taungpila there is a small mine known as Ma Sofia's Taungpila where a similar strike prevails and much tin-ore is obtained mixed with the wolfram.

South of the Taungpila group, the mines of the Wagon area are situated. As representatives of them we mention Tavoy Concessions' Thingandon area which lies on the western contact, and the Wagon Pachaung Wolfram Mines, Ltd., Wagon area, through which the eastern boundary passes. The Thingandon concession contains a number of lodes and patches of detrital ground. Although there are occasional lodes here showing an unusual strike

towards the E. of N., the general trend is about N.N.W.-S.S.E. The Thingandon ore is practically free from tin. One large lode crops out on the road side about 18 miles and 5 furlongs from Tavoy. It is from 4 to 5 feet thick, strikes N.W.-S.E. and dips at a high angle to the N.E. The country rock is granite and the lode has greisen walls carrying chlorite and molybdenite. The lode itself contains wolfram and molybdenite. Fluorite has also been obtained from it. The upper portions have been picked out and the workings can be seen rising over 300 feet in vertical extent from below the road.

The lodes in the eastern portion of the Wagon Pachaung Wolfram Co.'s area strike between N.E.-S.W. and N.N.E.-S.S.W. and are enclosed in sedimentary rocks. As a rule they carry large quantities of a pale green micaceous mineral, much pyrite, wolfram and a little cassiterite. On the western portion, made up of granite, the surface material, consisting of decomposed granite *in situ*, is rich enough to be treated by water under pressure and a concentrate carrying wolfram, cassiterite and iron oxides is obtained. Much of the ironstone is probably of secondary origin. Large masses of pure kaolin are often found in the sluice boxes. They appear to come from the weathered lodes and lead us to suspect that they are pegmatites.

East of the Central Range in this section and about three miles from it there is a roughly parallel and short ridge built up mainly of argillites and quartzites of the Mergui series. It is known as the Kyaukmedaung ridge and rises to 2,000 feet above sea level. On it are situated the Wagon North mine of the Burma Malaya Mining Co., Ltd., and the Rubber Mile mine of the Rangoon Wolfram Co., Ltd. Molybdenite occurs in larger quantities than usual in certain lodes of the first.

At the Rubber Mile the strike is generally N. by W. and S. by E., but the lode series is much faulted and broken and abnormal strikes towards east and west are common. The dip of these latter ones is to the south, while the more northerly and southerly lodes dip from vertical to the west.

At Wagon North on the west of the range the general trend is north and south, though here again east and west cross courses are known.

The lodes of both these mines probably originate from an underlying granite mass, the irregular portions of which appear to come

close to the surface in the sedimentaries. Large quantities of mica occur in the Rubber Mile lodes.

Four miles south of Rubber Mile and about 1 mile to the east of the main granite boundary is the peak Chaukto-wo Taung, 2,256 feet above the sea, on the N.E., south, and S.W. flanks of which a well developed flat lode crops out. It strikes N. 31° W.-S. 31° E. and dips towards the N.E. at 28°. The workings on this lode are known as the Heinda Mines and belong to Messrs. Steel Bros. and Co., Ltd.

The southern group of mines on the Central Range comprises the Paungdaw section. The most northern one, the Hon'ble Lim Ching Tsong's Putletto Mine, is usually regarded separately, but to avoid a multiplicity of terms we prefer to place it in the Paungdaw section to which it naturally belongs. It is situated on the granite contact towards the head of the Putletto valley. In this concession and the adjoining one to the south-east owned by Messrs. Steel Bros. and Co., Ltd., there are two series of lodes, one striking E. by N. and the other, carrying larger lodes, striking north and south. The lodes are in close proximity to the granite-sedimentary margin. In the north and south group there are eight parallel lodes all of which carry good wolfram values. The smallest is about 1 foot wide and the largest 6 feet wide. Here, as in other cases, we are only referring to the more important lodes. Actually upwards of thirty lodes of all sizes are known on the first concession alone. Bismuth compounds have been found in small quantities on both mines.

South of these mines is the Widnes mine of the High Speed Steel Alloys Mining Co., Ltd. It is within the outer granite margin, but contains patches of sediments lying on the upper surface of the granite. The workings are all on high ground over 2,000 feet in altitude. In the north-western corner is the peak Oktu Taung 3,875 feet above the sea. On the Anauktaung section at least seventeen lodes occur which are being systematically opened up underground. The surface of the spur in which they occur contains valuable detrital deposits which are worked by monitors. It is interesting to note that the upper surface of the lodes exposed in one portion of these workings end at the granite contact and do not penetrate into the overlying sediments, while in another place they go through from the granite into the argillites. The Shamataung section contains at least seven lodes which may belong

to the same series as those on Anauktaung. There are at least five lodes on the Aletaung section varying in thickness from 3 to 5 feet which have been traced for over 1,000 feet each in strike extension. Here the country rock is granite, deeply decomposed near the surface. These lodes possess the general strike, *viz.*, N. 15° E.-S. 15° W. and all dip at high angles to the east. Other lodes are worked in the Kalataung section. All of them carry wolfram in good quantities with large quantities of pyrite, while the tin content is low. On the Shamataung section there is an unusually large lode six to eight feet wide containing a little wolfram, some iron pyrites and relatively large quantities of molybdenite.

Adjoining the Widnes mine on the south is the Paungdaw mine of Messrs. Steel Bros. and Co., Ltd. A large number of lodes have been discovered in the granite which forms the high land on which the mine is situated. At least 10 important lodes are worked for wolfram. They are approximately parallel and strike N. 18° E.-S. 18° W. and all dip to the E. Like the lodes on Widnes mine, they possess unusually long strike extensions and are being explored by a deep crosscut. Iron pyrites is a very common lode mineral and small quantities of fluorite have been found. Workable detrital deposits are extensive.

Other mines in this region are owned by Messrs. Tata's, Ltd., and the London Burmese Wolfram Co., Ltd. They possess no unusual features. The mineral association is a sulphide one and the tin content is low, though individual lodes occur in which the percentage of cassiterite is high. Most of the Paungdaw lodes contain mica. They are usually bordered with mica walls when traversing sedimentary rocks and invariably have adjoining greisen bands in granite. Greisen bands frequently occur in the granite both here and elsewhere without any lode-quartz at all, and cases are known in which such bands have been worked for their wolfram content. Native bismuth has been found in southern Paungdaw.

The highest lodes of the district occur in this region on the Crest Mine of Messrs. Steel Bros. & Co., Ltd., at 400 or 500 feet below the summit of the Nwalabo peak, which has an elevation of 5,063 feet above sea level.

Three miles beyond the southern edge of the Paungdaw granite, but probably associated with a small exposure of granite in the Meke chaung, are the mines of the Meke area. These are leased by Maung Ni Toe and Lim Kyi Yan respectively. The lodes are

in sedimentary rocks, have the general strike trend of the Paungdaw ones, and contain sulphide of iron as well as wolfram. The lode ore does not contain much cassiterite, but it is found freely in the concentrates won from the detrital deposits. The greatest amount of tin-stone comes from the eastern end of Lim Kyi Yan's concession. The average tin content from Maung Ni Toe's mine is about 8 per cent.

The Southern Coastal Range.

This is a large granite intrusion which commences north of the Taungbyauk chaung and continues down towards the south approximately parallel with the coast line of the south of the district, a distance of nearly 30 miles from N.W. to S.E. before it enters the Mergui district. At its northern extremity the band is eight miles wide, but it narrows to five miles near the Mergui border. To the east of the granite mass there is a broad expanse of sedimentary rocks the eastern limit of which is not known at present. The granite forms high ridges culminating in Natya daung, 3,687 feet above the sea.

Its western contact with the sedimentary rocks in the vicinity of Sonsin and Mindat is known to be mineralised though no deposits of much importance have been discovered. Near Sonsin there are thin quartz lodes in the granite itself carrying molybdenite and a little wolfram. Cassiterite and bismuth ochre have been reported from the Nanpayok and Yange areas. The Pe concessions lie in the valley of the Pe chaung which flows south close to the eastern boundary of the granite. This district has only been opened up recently and as it is very inaccessible progress has been slow; the lodes appear to be small and to be usually in granite, especially where it has a thin covering of sediments. The general strike is N.W.-S.E., and the ore is low in tin-stone.

Tourmaline pegmatites occur between the western border of the Southern Coastal Range and the coast, but they contain neither wolfram nor cassiterite and are in no way connected with the ore-bearing lodes of the rest of the district.

The Ban-Tenasserim Divide.

A great granite intrusion has recently been discovered by the Geological Survey party in the high ridge separating the valleys of the Ban and Tenasserim Rivers. The rock of which it is built resembles the ordinary granite of the district. The intrusion commences in the latitude of Paungdaw and continues an unknown

distance south. Cassiterite has been obtained from the stream beds draining the granite, but prospecting operations are rendered most difficult by the absence of roads and villages and by the dense evergreen forests which cover this part of the country.

Cassiterite in the valley deposits of Tavoy.

Cassiterite occurs in the true alluvial deposits of streams draining the granite intrusions of the district or crossing their contacts with the overlying sedimentaries. Abundant evidence in the shape of ancient workings testifies to the amount of exploitation which they have undergone in the higher parts of the valleys in ancient times. In these parts the cassiterite occurs in narrow bands of gravel and sand close to the streams themselves and is easily obtained by ground sluicing. In the middle courses of the streams where the gradients are lower, wider placer deposits occur, often in the form of old river terraces and sometimes in shallow leads following the wanderings of an old bed. The one tin dredge which the district possesses at present is successfully operated by Messrs. Booth and Milne in the middle course of the Hindu Chaung. The concentrates contain cassiterite, topaz, magnetite, ilmenite, garnet, zircon, monazite and small amounts of gold. No attention has been paid in the past to the deeper deposits of the third portion of the streams where they broaden out and flow over the flat plains and are often tidal, but boring operations are in active progress at the present time in such situations.

Ancient gravel and pebble beds exist under the hill on which Tavoy itself stands. Cassiterite and gold with garnet, ilmenite, iron ores and zircon occur in it, and a portion of the hill has recently been taken out under a prospecting license in order to test the values systematically.

Mergui District.

The chief wolfram deposits of Mergui district are near Palauk in the north, and at Tagu near the Great Tenasserim River about 70 miles from its mouth.

The Palauk concessions are all small producers and their full development has probably been hindered by the difficulty of access to them. They lie partly in granite and partly on Mergui sediments, but the lodes worked are all in the latter. The lodes have a general E.-W. to N.E.-S.W. strike and are up to 1 foot in thickness. Molybdenite in small quantities occurs, as well as wolfram.

On Mr. E. Ahmed's Saku and U Shwe Ni's Nwebauk concessions native bismuth has been found in the alluvials in notable quantity; they all carry cassiterite.

On Spider Island, at the mouth of the Palauk river, is an interesting area in which concentrates containing cassiterite and wolfram in about equal amounts are obtained from the sea beach and from below high-water level in a mangrove swamp. The ore is derived from several small and irregular lodes traversing a little hill of Mergui sediments rising above the swamp.

To the south-east of the Palauk concessions, reached by a track, some 25 miles long from the Pyicha chaung, is a concession held by Messrs. Hand and Akbar Shah, but little is known about it.

In the Tagu region Mr. E. Ahmed's ranks with the best half dozen mines in the Tavoy district, having been a steady producer of about 14 tons per month for the past three years.

The lodes are all in granite and are remarkable for their large size. For instance, in the Kuntabin section of the mine, there are four lodes of 10-15 feet in thickness, one of 5 feet and three of 3 feet. The general strike is E.-W. Copper pyrites and arsenical pyrites occur in considerable quantities. Saw Lein Ni's mine adjoins Ahmed's and is geologically similar to it, but the lodes are smaller and less numerous. Here the predominant strike is E.N.E.-W.S.W. Between Tagu and the town of Tenasserim, on the right bank of the river, groups of concessions were taken out at Wunna and Mawton, but most have been given up and only one, U Shwe Thi's, has a steady though small output.

The Wunna areas are on Mergui sediments, the others on the margin of granite and sediments. The most usual lode strike here is N.W.-S.E. with numerous exceptions. A small deposit of stibnite of no economic value was discovered on one of the Wunna concessions, in a quartz lode which did not carry wolfram. All the Mergui wolfram deposits appear to carry cassiterite.

In the southern part of the Mergui district a wolfram-bearing reef occurs on Mr. Noye's concession at Yengan, and it used to be present, up to 25 per cent. wolfram, in the mixed ore mined by the Burma Development Syndicate at Maliwun. At the present time the concentrates obtained by ground sluicing there contain only 2-4 per cent.

Originally worked by the Chinese and subsequently by the Jelebu Co., Messrs. Strang, Steel & Co., and by the present Syndi-

cate, the Maliwun mine has been lavishly equipped with modern machinery, but has never been able to pay, and the hydro-electric generators, with mill, compressor, hydraulicking plant and electric tramways are decaying in the jungle, and only a small gang of Chinese tributers carry on the work. The lodes here are in granite very close to its margin with the Mergui sediments, and greisen veins are unusually common. There seems to be no definite strike. The lodes and greisen veins contain much white mica, and some pyrite, chalcopyrite and arsenopyrite. Tourmaline has also been recorded. The granite is identical with that of Tavoy. Alluvial cassiterite workings are widely distributed over the Mergui district, mostly held under "Native Methods" leases. Perhaps the best known centres are Karathuri on the coast and Thabawleik on the Little Tenasserim river, and there are numerous blocks on the Lenya and Pakchan rivers.

Of late years prospecting licenses have been issued to Messrs. Wightman's of Rangoon and others for alluvial cassiterite-bearing areas near Kazat and Nyumon in the delta of the Tenasserim, and near Palaw.

SUMMARY.

The foregoing notes demonstrate that all the wolfram and cassiterite lodes in Burma are closely associated with an intrusive granite, found throughout the province from the vicinity of the Southern Shan States to the extreme limit of the Mergui district, forming the cores of the mountain ranges known as the Indo-Malayan system. The granite is of a very acid type and is remarkably constant in composition and texture throughout the great distances it covers. It is intruded into a series of ancient slates, argillites, clay schists and silicified tuffs with subordinate quartzites and conglomerates of unknown age, known as the Mergui series in the southern districts of the Tenasserim division.

The Burmese ranges are only the northern extension of the great mountain system which stretches from the province into Western Siam and the Malay States.

The ores of tungsten and tin which are such characteristic minerals in the bearing lodes associated with this granite have unquestionably arrived in the lodes by some means or other from the cooling granite magma. Some of the sources of these ores are pegmatites and greisens and we believe that this fact gives

a clue to the presence of the same minerals in true quartz lodes of the ordinary type.

Detrital or eluvial deposits containing wolfram and cassiterite may occur on any hill slope in or above which the parent lodes are undergoing degradation, which is a comparatively rapid process in the rain-drenched regions of tropical Asia.

Alluvial or placer deposits containing cassiterite may be found in any stream draining a catchment in which bearing lodes occur. It is also possible to have concentrations of cassiterite in placer deposits without the occurrence of lodes, provided that the stream drains granite rocks carrying cassiterite as an accessory mineral.

Wolfram does not occur in true alluvial deposits in Burma, unless it is tightly enclosed in a surrounding matrix of quartz. The very perfect cleavage of this mineral results in its rapid disintegration on movement and in the production of a comminuted form eminently suited for chemical decomposition. Moreover wolfram is readily attacked by both acid and alkaline solutions which produce the friable yellow tungstite, or soluble alkaline tungstates, as the case may be. It is owing to these properties that wolfram never occurs free in true water-sorted sands or gravels which have been transported far from their sources.

In different parts of Burma, the mineral association of the ores is not the same. Beryl has only been found at Byingyi. At Mawchi, in Thaton and in parts of Mergui tourmaline occurs, but it is absolutely unknown as an associate in the Tavoy lodes, where fluorite has a wide though scanty distribution. The statement that the Tavoy lodes are characterised by the occurrence of tourmaline and columbite has obtained a wide circulation in the literature on the subject, but it is incorrect. Persistent search, extending over three years, has failed to reveal a single specimen of columbite. The association of wolfram and cassiterite with large quantities of pyrite and with smaller amounts of other natural sulphides, in nearly every known locality, is a remarkable and significant fact.

In conclusion we would point out that there are vast tracts of country lying between the known deposits of Burma which are very imperfectly explored. The producing deposits are all in the more accessible parts of the country; the intervening regions still await the attention of the prospector. We are not aware of any geological reason why more deposits should not be located,

provided favourable structural conditions are found. Our experience goes to show that the most promising situations in which to find new lodes lie in and about the contacts of the smaller and narrower granite intrusions, especially where patches of sedimentary rocks still remain on their surfaces, and prove that denudation has not removed the upper contact zone and the underlying portions of the granite itself.

LIST OF PLATES.

ON THE INCLINATION OF THE THRUST-PLANE OR REVERSED FAULT, BETWEEN THE SIWALIK AND MURREE ZONE OF FORMATIONS, NEAR KOTLI, JAMMU PROVINCE. BY C. S. MIDDLEMISS, C.I.E., B.A., F.G.S., F.A.S.B., *Superintendent, Mineral Survey of Jammu and Kashmir State.* (With Plate 28.)[1]

IN recent years new contoured 1″=1 mile maps of Jammu and Kashmir have been completed and issued by the Survey of India. To students of Himalayan geology, especially on its physical side, this is an event of special importance, because it enables them for the first time adequately and accurately to plot the folds into which the rocks are thrown, to gauge their absolute thickness and to measure the angle of inclination of the thrust-planes or reversed faults that separate zone from zone. It has been of the greatest importance to me in some recent survey work in Jammu province whilst engaged in enquiries of this nature dependent on accurate horizontal sections through the Sub-Himalayan zone.

In the present note I confine myself to an estimation of one of the above results on the basis of these new facilities, namely, the inclination of the thrust or divisional plane separating the younger zone of upper and middle Siwalik rocks (lying to the south-west) from the older Murree zone (lying to the north-east) in the neighbourhood of Kotli town in Jammu on the Punch river.

It has previously been usual in maps and sections of the Sub-Himalayan zone to represent fold-faults of this category as being fairly steeply inclined—something between the limits of 45° and 60° with the horizontal. In his latest important work (The structure of the Himalayas and Gangetic Plain, as elucidated by geodetic observations in India: *Mem. Geol. Survey of India,* Vol. XLII, pt. 2, p. 4) Mr. R. D. Oldham speaks of the main-boundary fault as being a 'nearly vertical plane of separation'; and, generally throughout the work, his diagrams indicate an approximately vertical inclination for it and for other similar parallel faults.

[1] Read at the Indian Science Congress, Bombay, January 1919.

It is safe to say that, in the absence of accurately contoured topographical maps having been used in their delineation, such a representation of the inclination of these faults is largely an assumption, or a generalised guess, founded on the appearance to the eye of the curves made by the trace of the fault as it wanders over the irregular surface of the country. I am also constrained to admit that eye impressions of the particular fault now under discussion at Kotli, based on this meandering of the trace at the surface, led me here also at first to imagine the angle as being something of the same kind, and certainly not lower in amount than 40° with the horizontal.

Actual plotting to scale of the curves of the Kotli fault, however, has told another story and shown that one is as easily misled in such a visual impression as one is in the inclination of a mountain slope when seen in complex perspective—and, not only misled, but grossly misled, as the following details will make clear.

The line of division, that is the trace of the fault, is particularly suited to definite plotting, because of the strong contrast presented by the formations on each side thereof. To the south-west, the younger series consists of very soft sandstones and shales (middle Siwalik) with synclinal troughs of conglomerate (upper Siwalik), all of pale ochre tints with the exception of a narrow band of bright red beds just near the boundary fault. To the north-east, however, the Murree series are more slab-like and indurated, and, above all, are of a totally different colour, being of a 'shot' purple and greenish grey or chocolate brown tint, which in the mass and distance produces the effect of a uniform rich rose-madder. No one for a moment could fail to place his finger (almost) on the exact line of separation, a feature that is emphasised also by a marked change in the hill contours, the steepening beginning with the Murree series and leaving its mark along the minor hill-spurs by a series of small indentations or gaps—just as happens constantly in many other similar parts of the Sub-Himalayas, a well-known example being just north of the Dehra Dun.

There is thus no difficulty or vagueness in laying down the line of this boundary-fault on the map, which in the area north-west and south-east of Kotli takes a course across country as follows:—Beginning some 5 miles north-west of Kotli at a point ⅓ mile N.E. of Galuhin it slants down into the unnamed river-bed, along a sharp curve, just north of the large village of Sarsawah,

thence passing round a series of spurs through the hamlet of Siyath continuing to east of Phanákha, just north of Chauki and thence sharply down again to the bed of the Punch river ½ mile due north of the dispensary at Kotli. From there it ascends again *viâ* Dhangrot, Mandiari, Dhambol, and Ishkiari.

These points can all be found on the map and if joined up will be seen to constitute an undulating curve that 'V's' up the stream and river-beds in a north-east direction and bellies outwards in the opposite direction round all the spurs.

On the other hand it is in my experience always practically impossible in Himalayan sections to see at the surface any evidence for the actual inclination of such a divisional plane, for the simple reason that in level spots there are no exposures and on all slopes surface-flexure vitiates observation.

If, however, in the case before us, we now join, with a straight line, such points along the trace on the spurs as are on the same contour, we can then measure the horizontal distance that the 'V'-ing up stream of the junction undergoes for a given drop in level. This in the case of the Sarsawah stream amounts to a horizontal distance of half a mile for a vertical drop of between 500 and 750 feet (and nearer the former). It corresponds to an angle of between 12° and 15° with the horizontal. In the position on the Punch valley at Kotli it amounts to a horizontal distance of less than half a mile (say 2,400 feet) for a vertical drop of 650 feet, which corresponds to an angle of 15° almost exactly.

This value then necessarily constitutes the true angle of inclination of the thrust-plane or reversed fault, and it is seen to be widely different from the estimate of about 40° that I had already come to by guess from eye observation alone.

The above result, although of interest in itself and in its bearings on Himalayan problems, is perhaps of more importance in the obvious, but none the less remarkable, lesson it teaches regarding what I may call *quantitative* geological surveying, and points the moral that with accurate contoured topographical maps, such as those now available for Kashmir and other parts of India, there is no longer any excuse for approximate guess-work in geological sections, but that all can now be plotted and worked out accurately to scale, whatever the nature of the geological or mineral fact it is desired to elucidate. By such means only can true estimates of real dip, of area, and cubic contents be worked

out, and all mineral positions and quantities calculated on a sure basis. Geologists who take full advantage of these important facilities will very soon repay in results the great debt they owe to the recent improvements initiated by the Survey of India in the construction of their standard sheets.

EXPLANATION OF PLATE.

PLATE 28.—Map showing trace of thrust-plane between Murree and Siwalik beds, Jammu. Scale 2″ = 1 mile.

TWO NEW FOSSIL LOCALITIES IN THE GARO HILLS. BY E. S. PINFOLD, B.A., F.G.S.[1]

PREVIOUS observers in the Garo Hills have confined their attention almost entirely to the coal-bearing Cretaceous rocks and the nummulitic limestones which immediately overlie them. Above the nummulitic rocks there is a considerable thickness of sandstones, quartz-pebble conglomerates and sandy shales, which, in recent maps, are coloured as Tipam or Siwalik. The discovery of recognisable and characteristic fossils in these rocks has now enabled us to fix their position in the sequence of the Indian Tertiaries with more certainty than has hitherto been possible.

The general structure of the Garo Hills is too well known to require any further description. The Tura hill range which crosses the region in a west-north-west direction is an ancient ridge of gneiss, certainly the oldest topographic feature in this part of India, for it appears to have existed in pre-Cretaceous times with much the same outlines as at present. The Tura ridge must have stood out of the Cretaceous sea as an island whilst the closely related Shillong plateau, its continuation eastwards, was submerged.

The Cretaceous rocks, coarse grits and sandstones with white kaoliniferous clay beds near the gneiss, rest against the steep face of the ridge with but little trace of disturbance. They are overlain by the nummulitic beds, chiefly remarkable for the pronounced change in their lithology from the Someswari section in the east to their final disappearance westwards about ten miles west of Tura. In the Someswari river these beds are limestones with only subordinate sandstones and shales; in the centre of the Garo Hills the limestones are much less conspicuous but are associated with a greater thickness of highly fossiliferous sandstones and shales. At Damalgiri, the most westerly extension of the fossiliferous nummulitic rocks, the total thickness of these beds is not more than about one hundred and fifty feet. They are here calcareous mud-stones with abundant nummulites and other fossils.

The beds which overlie the nummulitic rocks are soft yellow sandstones similar to the Tipam sandstones of Assam. These

[1] Read at the Indian Science Congress, Bombay, January 1919.

rocks occupy much the largest part of the low-lying plateau which stretches southwards from the Tura ridge. The dip is generally low to the south with local exceptions, and variable in amount, two to three degrees over long stretches with narrow zones of steep dips at times up to 60°. Such a zone of steep dips forms the southern boundary of the hill tract and this appears to be continuous with the steep southerly dips on the southern edge of the Shillong plateau. The jungle-covered country, and consequent lack of exposures, and the ill-defined bedding through the greater part of the series, makes it difficult to arrive at even a rough estimate of the thickness of these sandstones, though it is probably less than 10,000 feet.

The two fossil localities were found in the southernmost zone of steep dips, only a short distance north of the line along which the solid geology disappears finally beneath the alluvium of the Surma valley. It is clear therefore that these marine fossils are from the youngest rocks in this part of Assam.

The first locality observed is on the main road from Tura to Dalu four and a quarter miles north of Dalu. The road here passes through a low cutting and the fossil bed is clearly exposed on the left-hand side (going south towards Dalu). The dip is 5° southwards increasing to 30° further south in the hills nearer Dalu. The rocks containing the fossils are blue-gray shales with sandy hard beds; the beds immediately above and below the fossil horizon are yellow and brightly coloured sandstones with some sandy shales of the usual Tipam type. The fossil bed itself occurs in the middle of the blue shales; the fossils are to be found in the shale and in the sandy hard beds. Only one fossiliferous horizon appeared to be present, not more than three feet in thickness, crowded with well preserved shelly fossils.

The other locality is thirty miles east of Dalu near the Someswari river and the fossiliferous bed occurs here under exactly similar conditions. The foot-path which runs south-westwards from Bagmara village (the usual route from Bagmara to Dalu) passes through a narrow cutting about one mile from Bagmara and half a mile west of the Someswari and the fossil bed is clearly exposed on both sides. The rocks here are blue-gray shales similar to those of the Dalu locality though the sandy beds associated with the shales are somewhat less calcareous. As at Dalu, only a single fossiliferous bed is present and it is not more than three

feet in thickness. The dip is steeper, being 35° to 45° in a direction due south. The fossils in both localities are very numerous and for the most part well-preserved and easily extracted from the soft shales and sands, though the specimens are very friable and easily broken.

The fact that these occurrences are on approximately the same line of strike and occur in such similar stratigraphic conditions indicates that they are of about the same age if not, as seems probable, contemporaneous. Most of the forms present are common to both localities; *Turritella* is more abundant at Bagmara than at Dalu.

Many other sections between Bagmara and Dalu and to the east and west were examined but no other fossil occurrences were observed. The whole country, however, is very ill-exposed and largely under alluvium. The only other recorded occurrence of fossils at about this horizon in the Garo Hills is that discovered by Scott in the bed of the Brahmaputra in the early part of last century. This locality has never been rediscovered, in spite of the fact that there is a fairly good section exposed northwards from Mohindraganj in the cliffs which once formed the river banks. From what we know of the structure and the peculiarly isolated character of the Dalu and Bagmara fossil beds it seems very probable that the Brahmaputra marine fossils may have been laid down during the same marine transgression. An interesting feature in this connection is the occurrence of mammalian remains along with the marine forms, indicating the close proximity of a shore line in this direction. The Miocene sea appears to have extended somewhat further to the west than that of nummulitic times.

In the present state of our knowledge any attempt to correlate the succession in the Garo Hills with that of Assam is fraught with considerable uncertainty. As far east as Cherrapunji the section is satisfactorily definite, for the nummulitic limestone is present and the overlying sandstones and shales differ from the Upper Tertiary of the Garo Hills only in their steeper dips. As far as I am aware the sections in the Jaintia Hills have not been examined in detail and in the North Cachar Hills the nummulitic limestones have not been recorded and are probably absent. The presence of oil near the top of the Upper Tertiary of these hill tracts might be regarded as an unreliable indication that this series passes eastwards into the coal measures rather than into the over-

lying Tipam stage, which, in Lower Assam, does not contain oil. Further work would be necessary, however, before this could be regarded as satisfactorily definite.

The alluvial blanket south of the hill tracts cuts out the upper portions of this series, so that nothing can be said of its complete thickness or of the lithological character of the beds which are now obscured. The next exposures across the alluvial belt to the south are a series of sandstones and very coarse conglomerates which form the small isolated hills in the neighbourhood of Chhatak.

REPORT ON THE SANNI SULPHUR MINE. BY G. DE P. COTTER, B.A., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plate 29.)

THIS mine is situated in lat. 29° 2′ : long. 67° 29′ in the lands of the Rind chief of Shoran, and is 12 miles S.W. of Sanni, Kachhi district, Kalat State. It was formerly worked by the Afghans, and at intervals from the reign of Mir Mehrab Khan of Kalat onwards until the mine was closed down about forty years ago by Mir Khudadád Khan. It was visited by Masson, who travelled in Kachhi between 1827 and 1841. He informs us that the crude sulphur was carried to Bagh and there purified by boiling with oil (*sarson* oil).

Position and history of sulphur mine.

Captain Hutton saw the mine in 1846, and has left a short description.[1] He states that at that date there were several chambers entered by adits, and that the mineral was abundant. This is especially interesting since none of the local inhabitants remembers more than one entrance.

From information obtained locally I understand that the closing of the mines about forty years ago was the result of their having been maliciously set on fire. The fire must have burned for a long time, but I have no information on this point. The entire base of the cliff at the mine is concealed beneath a huge heap of ashes and debris, and my excavations have shown that the sulphur-rock has been burnt out and reduced to ashes even where it has been protected by the solid rock of the overhanging cliff. Within the mine the roof and walls are blackened, and the floor strewn with blackened sulphur-rock, but the fire has not been able to do much damage owing to want of air. Considering the extensive nature of the destruction, it seems reasonable to suppose that the fire lasted perhaps some years.

The Rind chief, whom I saw at Sanni, informed me that an attempt was subsequently made to open the mine, presumably when the fire had abated, or was supposed to be extinct. This attempt resulted in the deaths of a considerable number of miners,

[1] *Calcutta Jour. of Nat. Hist.*, VI, p. 562.

who were asphyxiated by the fumes within the mine. The bodies were recovered, and lie buried close by (see sketch-map, Plate 29). I counted 34 graves.

The mine was visited by my colleague Mr. G. H. Tipper in 1906. He found only one entrance, which had through disuse become partially choked with debris so that he was unable to examine the interior. He obtained, however, some specimens of alunogen and of sulphurrock. He observes that the sulphur occurs as veins and impregnations in Siwalik clays.[1]

My own visit to the mine began on 19th February, and ended on the 8th March 1919. Since I am writing this report from camp, and have not had an opportunity of examining my specimens in a laboratory, I propose to deal exclusively with economic questions, and to postpone the purely scientific results of my investigation.

Geology and structure of rocks at mine.

This report is accompanied by a sketch-map (see Plate 29) on which the geological formations and structure are shown. The east side of the map shows a flat plain covered by the gravel alluvium of the Bhitari River. The western half shows sandstones of Siwalik age, which rise from the plain as a steep scarp. This scarp is the northern end of the range which runs south past Shoran, on the margin of the Kachhi plain. The sulphur-rock, which is part of the strata at the base of the hill, is entirely concealed by a heap or fringe of ashes and debris, which covers the foot of the hill. It was only visible in one place, namely, the pit at the entrance to the mine where the ashes were partially cleared away. The rocks exposed on the hill are pink and buff sandstones, with occasional veins of selenite. There are a few bands of clay ironstone, and a sandy limestone with nummulites, the latter probably derived from Eocene rocks as detrital material. Mr. Tipper regards these rocks as Siwalik in age.

The strata are curved into the shape of a dome. Only half the dome is preserved, the other half being denuded and concealed beneath the gravels of the Bhitari river. From the map, it will be seen that the dips radiate from a central point somewhere near the south end of the dump heaps. This point is the summit of the dome, but unfortunately no rocks are visible here, and only the western portion of the dome remains.

[1] *Rec. Geol. Survey of India,* XXXVIII, p. 214.

Excavation of outcrops.

In excavating the sulphur-rock, I had two data to guide me. First, the ashes in front of the mine are most probably underlain by sulphur-rock *in situ*, and the limits of the ashes are probably roughly co-extensive with the limits of outcrop of the sulphur-rock. Secondly, there was one place, *i.e.*, the pit at the entrance to the mine, where the rock was actually exposed. With this knowledge, and the recognition of the structure as that of a dome, as described above, it was possible to predict at what depths and where the sulphur-rock might be found by digging. Accordingly four trenches were planned. as follows (see Plate 29) :—

Trench 1 to the north of the mine.

Trench 2 at the entrance to the mine.

Trenches 3 and 4, both south of the mine-entrance.

At the same time, I had the sand and rubbish cleared out of the adit to the mine, so as to enable me to examine the inside.

Trench 1.—Was dug right into the hill face from the margin of the ash heap. It was 87 feet long and 23 feet deep at the hill face, when a floor of hard rock was struck. Above this nothing but ashes and sandy debris were found. At a depth of about 20 feet a few sticks were seen. The flooring of hard rock at the bottom of the trench was laid bare for a distance of 21 feet. Right close up to the hill face, there appeared to be a hole in the floor of rock : this hole was filled with pieces of charred sulphur-rock, ashes and debris. The hole was excavated, and several pot-sherds, obviously broken earthenware pots, some pieces of charcoal, fragments of blackened sulphur-rock similar to that found in the interior of the mine, ashes and debris, were found. It was obvious that here was one of the old entrances alluded to by Captain Hutton, who, it will be remembered, in his visit in 1846 saw several adits, and not only one as now exists. This trench being exceptionally deep took a long time to excavate, and the old entrance was not found till March 6th. It was excavated to a further depth of 8 feet. The rock floor proved to be 5 feet thick and underneath this was debris on all sides. There appeared to be two roads, one to 20° S. of W., and the second in an opposite direction. I did not come upon any wall of hard rock at the sides, but only ashes and debris. Both passages were entirely filled up with fragments of sulphur-rock with blackened surfaces. As this old adit is probably stopped up for a considerable distance, its complete excavation would probably

have proved a lengthy task, necessitating a serious modification of my tour programme. I did not, therefore, follow the matter further: but the discovery of this old entrance will make it a fairly simple matter to ventilate the mine.

While taking out the debris from the old opening, I observed some long acicular crystals of alunogen growing on some of the ashy material. These crystals had clearly been formed after the conflagration, possibly by being leached out of the debris and redeposited, or else as the result of the action of acid vapours given off from the hot mine acting upon the alumina of the rocks.

The vertical section of sulphur-rock exposed at this old opening was 5 feet. An average sample of this rock was taken by chipping out pieces from top to bottom with hammer and chisel, thoroughly mixing, coning and quartering. This sample (No. 6) was assayed in the laboratory of the Geological Survey of India, with the following results:—

	Per cent.
Total sulphur	26·30
Combined sulphur	8·31
Available sulphur	17·99

It will be observed here that the thickness of the sulphur-rock is at least 5 feet. But it is probably considerably more, because above the rock were ashes, probably of a softer sulphur-bearing stratum, and beneath were ashes and debris, where there was probably originally sulphur-rock. It seems therefore probable that the sulphur-rock was originally at least 10 feet thick here.

In the upper part of the cliff face at this trench, there were certain bands of yellow-stained sandy clay. The yellow stains were said to be due to the presence of *zagh*, which is the Baluchi name for melanterite. I tested some of this in the field by dissolving in water and adding ammonia. I obtained only the white alumina precipitate. Nevertheless some of the specimens do possibly contain a certain amount of ferrous sulphate, but this point cannot be settled till further analyses have been made.

Trench 2.—At the entrance to the mine there is a vertical height of 10 feet 7 inches of sulphur-rock. Above is bleached sandy clay stained with yellow sulphur in places, but calcined partially by fire. The outer (eastern) wall of the mine entrance shows the same sulphur-rock in a burnt condition. It has not in this case been reduced to ashes, but is a hard black vesicular rock very like a lava and

probably analogous to the products formed when a coal seam burns at the outcrop. More cannot be said until this rock has been examined microscopically. In the floor of the trench east of the entrance some hard sulphur-rock was laid bare. An average sample (No. 2) was taken from the vertical thickness of 10 feet 7 inches of sulphur-rock exposed at the entrance to the mine and yielded the following result on assay in Calcutta :—

	Per cent.
Total sulphur	38·35
Combined sulphur	1·43
Available sulphur	36·92

In this exposure, we do not see the bottom of the sulphur-rock. Underneath the 10 feet 7 inches of rock is the floor of the adit, which could not have been deepened with the tools at my disposal and for which blasting or boring operations would have been necessary. It is possible therefore that the sulphur-rock may be considerably thicker.

Trench 3.—This trench was cut deep into the cliff wall. At the top of the trench is exposed a stratum impregnated with a yellow incrustation called *zagh* by my coolies. Whether it is melanterite or not will be decided later after examination in Calcutta. There are also some bands and pockets of cherry-coloured iron ochre. The rock is friable and appears to have been subjected to great heat. Below this are 7½ feet of a soft powdery rock, which I regard as ashes of a sulphur-impregnated rock. Below these ashes are 4 feet 1 inch of sulphur-rock, from which an average sample (No. 3) was taken, which on analysis showed :—

	Per cent.
Total sulphur	27·10
Combined sulphur	1·38
Available sulphur	25·72

This sulphur-rock was exposed along the floor of the trench for a distance of 21 feet horizontally. Below the 4 feet of rock, I found a powdery clay, which appears to be ashes of sulphur-rock; but I could not excavate any deeper, as the trench had now gone well into the hill-side, and further work would have necessitated timber supports to the overhanging rock.

Although there are only four feet of sulphur-rock to be seen here, there is evidence that the sulphur was formerly much more extensive, and has been in great part burnt out.

It must be understood that it is of no use examining the sides of the trenches, which consist entirely of ashes and debris. It is only at the head of the trench where it scoops into the hill face that the genuine rock *in situ* is to be seen. For this reason, it is not possible to carry the trenches beyond a certain point without timbering, which I was not in a position to undertake in these operations, which were, in consequence, stopped in each case when I considered that the margin of safety had been reached.

Trench 4.—This trench is remarkably similar to trench 3. On the top is a layer 1 foot thick of *zagh*-impregnated rock, above which is a roof of hard conglomerate. Below the layer of *zagh* were 6½ feet of ashy clay. Below this again were 5 feet of sulphur-rock. On the south side of the trench this rock had been reduced to ashes, but it was hard and firm on the north side. A sample (No. 4) of this rock was taken, and on essay yielded the following results :—

	Per cent.
Total sulphur	28·11
Combined sulphur	0·82
Available sulphur	27·29

The four trenches above described all expose the same stratum of sulphur-rock, and there is evidence that this rock is about 11 feet thick, taking into consideration the ashy strata, which must have been originally sulphur-rock. What lies beneath the 11 feet of sulphur-bearing rock we do not know, and it is not at all improbable that there are further sulphur-impregnated strata beneath. We may, however, assume a thickness of about 11 feet on the average for the sulphur-bearing strata in the four trenches. It is true that it has been largely burnt out, but, for reasons which I shall afterwards state, I do not consider that the burning is likely to have affected the rocks to any great depth.

Examination of interior of mine.

I attempted to map, by means of a pocket compass and tape, the passage leading into the mine. It runs northward from a pit at the mouth about 8 feet deep and is 185 feet long and very tortuous. Commencing as an adit, it is fairly level for the first 75 feet, after which it becomes an incline and descends fairly gently for about 50 feet; the slope then becomes rather steep, probably from 30° to 35° for 60 feet, when a vertical winze 8 feet deep runs into a large

chamber 20 to 30 feet across, from which two galleries run, one in a N. W. direction and the other in an easterly direction. I saw some other openings, but I am not sure whether they were galleries or only short burrows.

The incline appears to pass through sulphur-rock all the way. The walls and roof are blackened, but there is little sign of actual burning. One piece of timber still remains. Its outside is blackened, but the wood has not been burnt. Between 75 and 100 feet in from the mouth, the rocks are impregnated with alunogen, or *phitki* as the Baluchis call it.

The gallery which runs N. W. changes its direction to N. after some distance, perhaps 60 to 80 feet or so. About 200 feet down, there are small pools containing mineral tar and acid water. Specimens of both were obtained, and dispatched to Calcutta for analysis.

The floor of the gallery is strewn with fragments of sulphur-rock, which are blackened by the smoke of the fire. The roof of the gallery has a curious knobby appearance and is also blackened. It is possible that the sulphur has run to a certain extent, so as to fill up crevices and impart this smooth appearance to the roof.

A sample (No. 1) of the loose fragments of sulphur-rock on the floor of the mine was taken for analysis, and yielded the following results on assay :—

	Per cent.
Total sulphur	**37·63**
Combined sulphur	**1·59**
Available sulphur	**36·04**

In most parts of the gallery one has to stoop very low, but it is possible to stand upright in places and in the central chamber there is plenty of standing room. The air in the incline is hot and unpleasant, but that in the interior of the mine is fiercely hot. It is not, however, the heat which renders the interior unsafe, but the vapours which contaminate the air. The acid water of the pools in the galleries must give off a certain amount of carbon dioxide, whenever any calcareous matter is wetted in the course of percolation, and in addition there is a certain amount of sulphur dioxide or else of sulphuretted hydrogen fumes, possibly the latter, as a silver watch chain turned black during my inspection. The fumes, whatever they were, caused dizziness and smarting of the eyes and gave rise to a headache, and it was plain that no sort of examination of the interior could be made without some means of ventilation, and I did not

attempt, therefore, to explore the old workings further. Before any attempt is made to explore the mine further, I should recommend that the old adit which I discovered in trench 1 should be opened up, and a current of air drawn by means of an exhaust fan through the mine.

Quantity of sulphur-rock available.

Since the trenches have exposed the sulphur-rock along the strike at four points, and since the incline and mine gallery follow the rock down the dip, we have several points where we know that the rock undoubtedly exists. We may, therefore, assume that the sulphur-rock is continuous between any two points where it is exposed. From a consideration of the known exposures as mapped on my sketch-map, I calculate that the rock is almost certainly spread over an area of 70,000 sq. feet. Assuming that the thickness is 11 feet on the average, this gives us 770,000 cubic feet of sulphur-rock. From this it is necessary to deduct the quantity of sulphur-rock already extracted, and the quantity destroyed by fire.

I do not think the damage by fire has been great, except close to the surface. The interior of the mine is blackened. but not seriously burnt. The sulphur-rock was found in fresh condition in the trenches after digging away the surface ashes, and although the fire has eaten in places six or eight feet into the hill, I imagine that this is about the total extent of the damage.

It is harder to estimate the amount of rock extracted from the mine, since no complete survey could be made. I think, however, that if we reduce the calculated volume by one-fourth, we shall probably be near the mark. This reduction would in my opinion be enough and leaves a net total of 577,500 cubic feet of sulphur-rock. Assuming a specific gravity for the sulphur-rock of 2·25—complete determinations will be made on my return to headquarters—this volume corresponds to about 36,000 tons of sulphur-rock. The five samples, of which the assay results have been given, show an average of 28·79 of available sulphur. This corresponds to slightly over 10,000 tons of sulphur.

The estimate given above is a conservative one, for it does not take into account the possibility that the sulphur-rock is more than 11 feet thick, nor the possibility that it extends westwards beyond the limits of the gallery visited. But it is extremely probable that there is such an extension to the westward. I also think it likely that the strata which carry sulphur are more than 11 feet

thick; for the adit, although tortuous and descending rapidly in places, does not appear to leave the sulphur-bearing strata.

It is probable that the sulphur has impregnated the softer layers of sandy clay underlying the pink and buff sandstones of the scarp, and that it has been deposited over a more or less circular area, in the centre of which there must have been a fumarole. If it is the result of fumarolic action, the deposit would naturally tend to assume a cylindrical shape, but would be limited to the softer and more easily impregnated strata, and would also be confined to the particular part of the fumarole where the conditions of temperature were favourable to the deposition of sulphur. We must expect then both that the sulphur is limited in depth, because the higher temperatures beneath did not allow of the deposition of sulphur, and also that it is more or less confined (at least as a rich deposit) to the softer strata.

While we are justified in hoping that the sulphur-rock may be more than 11 feet thick, it does not seem likely that the deposit is *vastly* greater than the estimate of probable amounts of sulphur-rock given above. There may be double the estimated amount of rock present, but it is very unlikely that there is, say, ten times the estimate.

Prospects of working.

I have not at present sufficient data at my disposal to enable me to discuss satisfactorily the economic possibilities of working this mine. I may mention, however, that it is situated 40 miles from Bellpat, the nearest railway station, and 37 miles from Rindli on the Bolan Pass cart-road, and that the cost of transport to the railway either by cart or camel will be considerable. The cost of labour is also relatively high, *viz.*, about 12 annas per day. Furthermore, the cost of extraction of the sulphur from the rock will also be high owing to the high price of fuel in Baluchistan.

Other products of mine.

The quantities of maltha (mineral tar) and of alunogen appear to me to be too small to be of commercial value, but these and also the acid water are of great scientific interest. In a future note I hope to advance reasons for the belief that the sulphur has been deposited by a fumarole or by a mineral spring.

EXPLANATION OF PLATE.

PLATE 20.—Sketch-map of sulphur mine 12 miles S.W. of Sanni. Scale 1″=100 feet.

MISCELLANEOUS NOTES.

Note on a Spiral Impression on Lower Vindhyan Limestone (Pl. 30).

The impression forming the subject of this note was found in the talus of the Vindhyan scarp at Saraidanr near Rhotas, and was apparently derived from about the middle of Mallet's division 9 of the Lower Vindhyans (*Mem., G. S. I.*, VII, p. 27), which constitutes the main mass of the Rhotas limestone. This is here a thin-bedded limestone consisting of grey and yellow compact slabs of one inch or less in thickness, alternating with thin partings of creamy-white, more shaly, and often decomposed layers. A noteworthy point is the occurrence, within the limestone, of small scattered crystals of blue and purple fluor-spar, which has hitherto not been recorded from this horizon, though mentioned by Mallet in the case of Bandair limestone in the Upper Vindhyans.

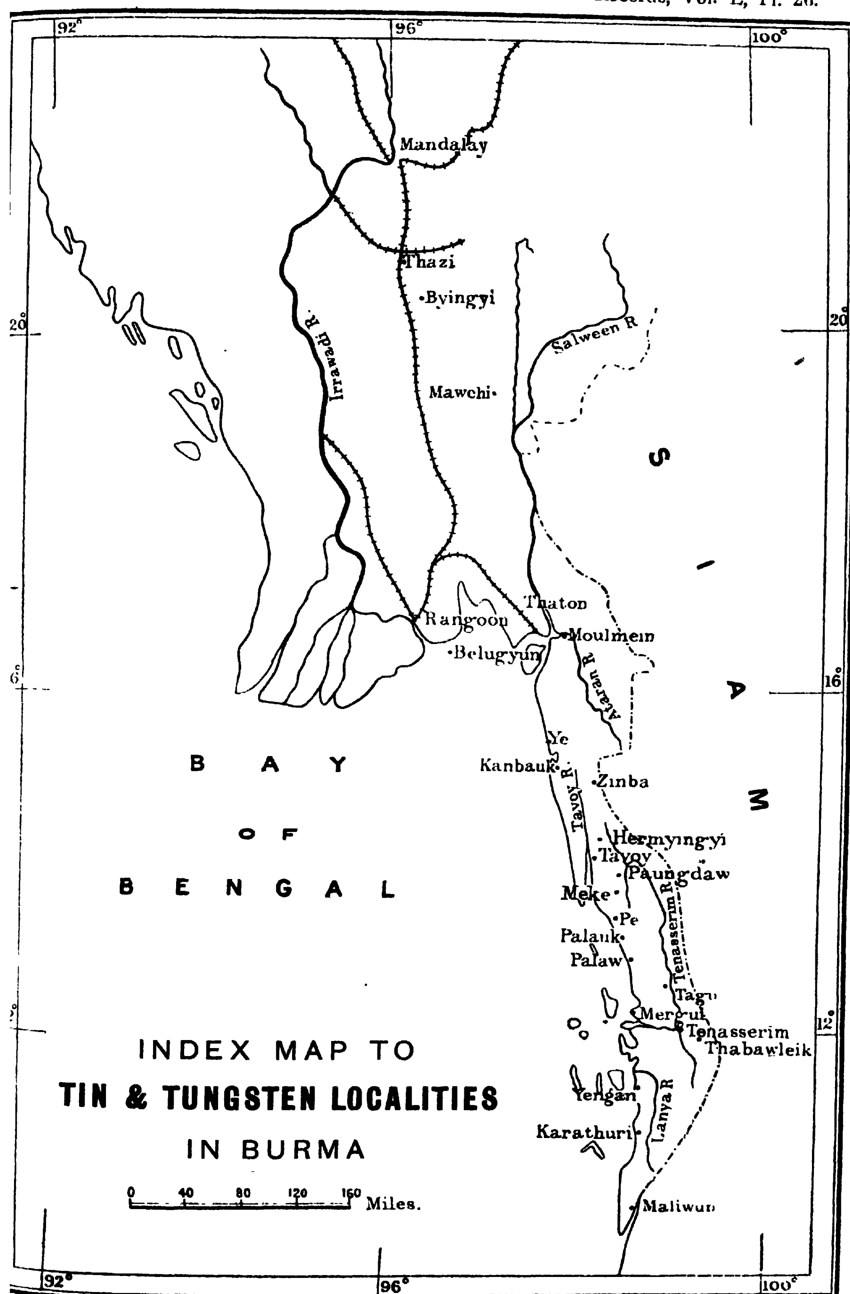
The specimens include both the impression on the upper surface of one of the softer shaly layers, and its cast in relief on the under surface of the overlying slab of hard compact limestone (Pl. 30). No other markings have been observed in the rock, though the abundant quarry-refuse, new and old, all along the outcrop, was carefully searched for a distance of several miles.

The impressed specimen, which measures 13 mm. × 11 mm., has the appearance of a small spiral groove, such as might be caused by the impression left on the surface of the soft mud by the dead body of a small coiled worm, or else such as might represent a track of some small burrowing animal. Though sharply delineated, it shows no structure other than some obscure transverse wrinkles, and even its organic origin is doubtful. Nevertheless, owing to the scarcity of organic or even pseudo-organic markings in the Vindhyan system, it has been thought advisable to draw attention to this occurrence.

[E. J. BEER.]

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

Records, Vol. L, Pl. 26.



G. S. I. Calcutta.



× 6



Natural size.

Photo K. F. Watkinson. *G. S. I Calcutta.*

SPIRAL IMPRESSION ON LOWER VINDHYAN LIMESTONE.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1919. [September.

THE MINERAL PRODUCTION OF INDIA DURING 1918. BY

H. H. HAYDEN, C.S.I., C.I.E., F.R.S., *Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these *Records* (Vol. XXXII),

although admittedly not entirely satisfactory, is still the best that can be devised under present conditions. The methods of collecting the returns are becoming more precise every year and the machinery employed for the purpose more efficient. Hence the number of minerals included in Class I—for which approximately trustworthy annual returns are available—is gradually increasing, and it is hoped that before long the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will be reduced to a very small number. In the case of minerals still exploited chiefly under primitive native methods and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible, but the total error from year to year is not improbably approximately constant and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small indigenous alluvial industry contributes such an insignificant portion to the total outturn that any error from this source may be regarded as negligible.

From table 1 it will be seen that there has been an apparent increase of nearly £2½ million or 18 per cent. in the value of the total production over that of 1917. The value figures, however, are largely artificial. In some instances although the output has fallen in quantity, it has increased in value; such increase does not necessarily give a true indication of the state of an industry, since the prevailing high freights and increased cost of production have in certain cases resulted in the closing down of all but high-grade propositions. Further anomalies are introduced by changes in the rate of exchange. The value of the rupee during the year 1918 rose to 1*s*. 6*d*. For purposes of comparison, however, the old rate of exchange has been retained and the sterling values shown in table 1 have been derived from rupee values by conversion at the rate of Rs. 15=£1. In all the other tables, except tables 16 and 30, the value of the production has been shown in rupees as well as in sterling.

Mineral Concessions granted.

The number of mineral concessions granted during the year amounted to 719 as against 574 in the preceding year; 675 of these were prospecting licenses and 44 mining leases. As in the preceding year, most of the increase is due to prospecting activity in Lower Burma.

TABLE 1.—*Total value of Minerals for which returns of Production are available for the years 1917 and 1918.*

——	1917.	1918.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Coal	4,511,645	6,017,089	1,505,444	..	+33·4
Gold	2,221,889	2,060,152	..	161,737	—7·3
Salt	983,157	1,644,211	661,054	..	+67·2
Manganese-ore(*a*)	1,501,080	1,481,735	..	19,345	—1·3
Petroleum	1,092,965	1,131,904	38,939	..	+3·6
Tungsten-ore	623,074	726,321	103,247	..	+16·6
Mica(*a*)	508,173	625,741	117,568	..	+23·1
Saltpetre	527,666	589,190	61,524	..	+11·7
Lead and Lead-ore	397,478	450,477	52,999	..	+13·3
Silver	237,216	295,696	58,480	..	+24·7
Building materials	249,776	238,355	..	11,421	—4·6
Tin and Tin-ore	94,495	134,635	40,140	..	+42·5
Jadestone(*a*)	67,502	124,113	56,611	..	+83·9
Monazite	56,489	58,819	2,330	..	+4·1
Chromite	26,215	52,063	25,848	..	+98·6
Iron-ore	39,977	47,298	7,321	..	+18·3
Ruby, sapphire and spinel	51,831	40,310	..	11,521	—22·2
Clay	9,020	13,623	4,603	..	+51
Steatite	6,470	10,921	4,451	..	+68·1
Magnesite	14,559	4,641	..	9,918	—68·1
Corundum	3,875	4,106	231	..	+6
Copper-ore	30.162	4,053	..	26,109	—86·5
Apatite	..	3,400	3,400	..	..
Barytes	..	2,948	2,948	..	..
Diamond	1,826	2,625	799	..	+43·7
Ochre	1,629	1,959	330	..	+20·2
Gypsum	1,035	1,139	104	..	+10·1
Asbestos	303	965	662	..	+218·5
Alum	3,707	960	..	2,747	—74·1
Bauxite	620	894	274	..	+44·2
Graphite	547	361	..	186	—34
Aquamarine	297	180	..	117	—39·4
Amber	684	87	..	597	—87·3
Molybdenite	626	62	..	564	—90·1
Potash	..	46	46	..	..
Antimony-ore	139	...	..	139	..
Samarskite	2	4	2	..	+100
Platinum	19	2	..	17	—89·5
Agate	255	..	..	255	..
Bismuth	163	..	..	163	..
Total	13,266,566	15,771,085	2,749,355	244,836	+18·8
			+2,504,519		

(*a*) Export values.

II.—MINERALS OF GROUP I.

Chromite.	Gold.	Lead.	Monazite.	Salt.
Coal.	Graphite.	Magnesite.	Petroleum.	Saltpetre.
Copper.	Iron.	Manganese.	Platinum.	Silver.
Diamonds.	Jadeite.	Mica.	Ruby, Sapphire and Spinel.	Tin.
				Tungsten.

Chromite.

There was a very marked increase, amounting to more than 100 per cent., in the output of chromite during the year 1918. This was due partly to increased output in Baluchistan but chiefly to the rapid development of a recently discovered property in Mysore.

Table 2.—*Quantity and Value of Chromite produced in India during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Baluchistan . .	15,659	2,34,885	15,659	22,944	3,44,160	22,944
Bihar and Orissa .	3,266·4	46,657	3,110·5	1,085·5	24,666	1,644·4
Mysore . .	8,136	1,11,684	7,445·6	33,740	4,12,115	27,474·3
Total .	**27,061·4**	*3,93,226*	*26.215·1*	**57,769·5**	*7,80,941*	*52,062·7*

Coal.

There was an increase of over 2½ million tons, or about 14 per cent., in the output of coal. With the exception of Assam and Hyderabad, where the output decreased by about 7,000 and 21,000 tons respectively, all Indian provinces shared in this increase. The pit's mouth value increased largely everywhere, except in the North-West Frontier Province where it fell from Rs. 14 to Rs. 4 per ton, but as the output in the latter province was only 240 tons, the figure has no statistical value. In the fields of Bengal and Bihar and Orissa, the rates of increase were respectively Re. 0-15-9 and Re. 0-8-5 per ton or 25 and 16 per cent.

TABLE 3.—*Average price (per ton) of Coal extracted from the Mines in each province during the year 1918.*

Province.	Average price per ton.		
	Rs.	A.	P.
Assam	7	2	8
Baluchistan	14	13	8
Bengal	4	14	10
Bihar and Orissa	3	14	3
Central India	4	8	1
Central Provinces	5	9	0
North-West Frontier Province	4	0	0
Punjab	11	5	0
Rajputana	6	5	5

TABLE 4.—*Origin of Indian Coal raised during 1917 and 1918.*

	Average of last five years.	1917.	1918.
	Tons.	Tons.	Tons.
Gondwana Coalfields	16,640,958	17,814,524	20,321,942
Tertiary Coalfields	407,728	398,394	399,601
Total	..	**18,212,918**	**20,721,543**

TABLE 5.—*Provincial Production of Coal during the years 1917 and 1918.*

Province.	1917.	1918.	Increase.	Decrease.
	Tons.	Tons.	Tons.	Tons.
Assam	301,480	294,484	..	6,996
Baluchistan	40,785	43,125	2,340	..
Bengal	4,631,571	5,302,295	670,724	..
Bihar and Orissa	11,932,419	13,679,080	1,746,661	..
Central India	198,407	199,975	1,568	..
Central Provinces	371,498	481,470	109,972	..
Hyderabad	680,629	659,122	..	21,507
North-West Frontier Province	215	240	25	..
Punjab	49,869	50,418	549	..
Rajputana	6,045	11,334	5,289	..
Total	**18,212,918**	**20,721,543**	*2,537,128*	*28,503*

TABLE 6.—*Output of the Gondwana Coalfields for the years 1917 and 1918.*

—	1917.		1918.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Bengal, Bihar and Orissa—				
Daltonganj	79,627	·44	81,816	·39
Giridih	824,007	4·52	846,592	4·09
Jainti	86,894	·48	140,373	·68
Jharia	9,783,788	53·72	10,951,060	52·85
Bokaro-Ramgarh . .	360,760	1·98	541,977	2·62
Raniganj	5,376,022	29·52	6,368,519	30·74
Sambalpur (Hingir-Rampur)	52,892	·29	51,038	·25
Central India—				
Umaria	198,407	1·09	199,975	·96
Central Provinces—				
Ballarpur	95,303	·52	135,375	·65
Pench Valley . . .	204,502	1·12	267,303	1·29
Mohpani	71,693	·39	78,792	·38
Hyderabad—				
Singareni	680,629	3·74	659,122	3·18
Total .	**17,814,524**	**97·81**	**20,321,942**	**98·08**

TABLE 7.—*Output of Tertiary Coalfields for the years 1917 and 1918.*

—	1917.		1918.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Assam—				
Makum	291,484		267,749	
Naga Hills	8,906	1·65	24,299	
Sibsagar	915		1,827	1·42
Khasi and Jaintia Hills .	175		609	
Baluchistan—				
Khost	29,517	·22	29,600	·21
Sor Range	11,268		13,525	
North-West Frontier Province .	215		240	
Punjab—				
Jhelum	40,322	·29	39,651	·24
Mianwali	2,916		5,152	
Shahpur	6,631		5,615	
Rajputana—				
Bikaner . .	6,045	·03	11,334	·05
Total .	**398,394**	**2·19**	**399,601**	**1·92**

Exports of coal fell to less than 75,000 tons. Imports, on the other hand, rose from 46,000 tons to 67,000 tons.

TABLE 8.—*Exports of Indian Coal.*

—	1917.		1918.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Ceylon	299,070	181,250	51,935	36,442
Straits Settlements (including Labuan).	80,077	49,495	10,279	6,853
Sumatra	8,474	5,731	...	...
Other Countries	19,457	14,269	12,121	8,703
TOTAL	407,078	250,745	74,335	51,998
Coke	1,039	1,813	131	346
Total of Coal and Coke	**408,117**	*252,558*	**74,466**	*52,344*

TABLE 9.—*Imports of Coal, Coke and Patent Fuel during 1917 and 1918.*

—	1917.		1918.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons	£
Australia (including New Zealand).	22,554	37,551	4,857	9,741
Natal	3,857	6,484	13,020	29,805
Portuguese East Africa	9,080	14,844	22,680	37,416
United Kingdom	5,875	19,273	7,580	33,944
Other Countries	2,422	4,929	5,065	17,578
TOTAL	43,788	83,081	53,202	128,484
Coke	1,026	4,644	1,144	6,227
Patent Fuel	4	152	...	11
Government Stores	1,637	4,222	13,095	54,037
Total	**46,455**	*92,099*	**67,441**	*188,759*

The average number of persons employed daily in the coalfields increased by 24,000 or more than 14 per cent. The average output per person employed was practically the same as in the preceding year, *viz.*, 108·3 tons as against 108·88. The total number of fatal accidents was 212, corresponding to a death rate of 1·11 per thousand.

TABLE 10.—*Average number of persons employed daily in the Indian Coalfields during 1917 and 1918.*

Province.	Number of persons employed daily.		Output per person employed.	Number of deaths by accidents.	Death-rate per 1,000 persons employed.
	1917.	1918.	1918.	1918.	1918.
Assam . . .	2,952	3,085	95·5	13	4·21
Baluchistan . .	955	993	43·4	2	2·01
Bengal . . .	38,585	46,149	114·9	71	1·53
Bihar and Orissa .	106,571	118,845	115·1	104	·87
Central India . .	1,244	3,047	65·6	1	·33
Central Provinces .	4,245	6,052	79·5	7	1·16
Hyderabad . .	11,566	11,582	56·9	14	1·21
North-West Frontier Province.	14	12	20	...	...
Punjab . . .	1,033	1,358	37·1	...	...
Rajputana . .	107	198	57·2	...	...
Total .	167,272	191,321	..	212	..
AVERAGE .			108·3		1·11

Copper.

The output of copper ore in Singhbhum fell from 20,108 tons in 1917 to only 3,619 tons valued at Rs. 60,795 (£4,053). Smelting operations began at the Rakha Mines during the year and resulted in the production of 13·16 tons of blister copper.

Diamonds.

The output of diamonds amounted to 73 29 carats valued at Rs. 39,377 (£2,625) as against 18·2 carats valued at Rs. 27,396 (£1,826) in the preceding year.

Gold.

There was a decrease, amounting to 38,175 oz., in the output of gold. All provinces shared in this decrease which, however, was borne chiefly by the Mysore fields where the output fell by 32,147 oz.

TABLE 11.—*Quantity and value of Gold produced in India during 1917 and 1918.*

—	1917.			1918.			Labour.
	Quantity.	Value.		Quantity.	Value.		
	ozs.	Rs.	£	ozs.	Rs.	£	
Bihar and Orissa—							
Singhbhum .	2,462	1,52,000	10,133	2,085	1 48,573	9,905	183
Burma—							
Myitkyina .	1,005·55	58,428	3,895	105·57	6,069	404	232
Katha . .	31·19	1,690	113	19·23	1,060	71	
Upper Chindwin	42 18	3,600	240	46·40	3,960	264	
Hyderabad . .	13,466·7	7,80,202	52,013	11,502·8	6 74,046	44,936	1,155
Madras . .	20,529	13,05,989	87,066	17,831	10,08,279	67,219	1,004
Mysore . .	536,559	3,10.13,115	2,067,541	504,412	2,90.51,774	1,936,785	24,517
Punjab . .	190 08	12,848	857	109·95	8,119	541	204
United Provinces	7·31	468	31	6 37	398	27	19
Total .	**574,293·01**	*3 33,28,340*	*2,221,889*	**536,118·32**	*3,09,02,278*	*2,060,152*	**27.314**

Graphite.

There was a further reduction in the output of graphite which fell from 102·7 tons valued at Rs. 8,205 in 1917 to 81 tons valued at Rs. 5,410 in the year under review. This was due to the extinction of the graphite industry in Rajputana where only 1 ton was produced as against 42·3 tons in 1917. In Kalahandi the output rose from 60 to 80 tons.

Iron.

There was a considerable increase in the output of iron-ore. The Tata Iron and Steel Company produced 198,064 tons of pig iron and 130,043 tons steel including rails, while the Bengal Iron and Steel Company produced 49,348 tons of pig iron, 12,114 tons of ferro-manganese and 21,776 tons of cast iron castings. In the Central Provinces there was a reduction of nearly 25 per cent. in the number of indigenous furnaces, which fell from 312 in 1917 to 232 in the year under review.

TABLE 12.—*Quantity and value of Iron-ore produced in India during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar and Orissa—						
Singhbhum .	184,815	2,06,671	13,778	120,363	1,27,239	8,483
Orissa . .	195,998·5	2,63,144	17,543	339,304·6	4,52,163	30,144
Burma . .	28,763	1,15,052	7,670	26,680	1,06,720	7,115
Central Provinces	3,669	14,676	978	6,097	23,185	1,546
Rajputana .	25	100	7	38	152	10
United Provinces	2·2	9	·6	1·6	6	...
Total .	**413,272·7**	*5,99,652*	*39,976·6*	**492,484·2**	*7,09,465*	*47,298*

Jadeite.

There was a decrease of nearly 20 per cent. in the output of jadeite in Burma, which fell from 3,961·28 cwt. valued at Rs. 4,33,968 (£28,931) in 1917 to 3,203·1 cwt. valued at Rs. 3,78,135 (£25,209), in the year under review.

Lead.

Although there was a decrease in the amount of ore and slag produced at the Bawdwin mines, the amount of metal extracted was greater than that recovered in the year 1917, the total output being 19,074 tons valued at Rs. 67,51,842 (£450,123) as against 16,962·13 tons valued at Rs. 59,37,050 (£395,803) in the preceding year. The quantity of silver extracted rose from 1,580,557 oz. valued at Rs. 35,56,253 (£237,083) in 1917 to 1,970,614 oz. valued at Rs. 44,33,881 (£295,592) in the year under review.

TABLE 13.—*Production of Lead and Silver ore during 1917 and 1918.*

—	1917.					1918.				
	QUANTITY.	VALUE.				QUANTITY.	VALUE.			
	Lead-ore and slag.	Lead-ore and lead.		Silver.		Lead-ore and slag.	Lead-ore and lead.		Silver.	
	Tons.	Rs.	£	Rs.	£	Tons.	Rs.	£	Rs.	£
Burma—										
Northern Shan States.	54,616 (ore)	52,68,200(*a*)	351,213	34,31,347	228,756	50,679 (ore)	61,97,478(*f*)	413,165	41,50,793	276,720
	6,282 (slag)	5,60,350(*b*)	37,357	65,416	4,361	2,042 (slag)	2,69,040(*g*)	17,936	26,388	1,759
	10.589 (gossan flux)	1,08,500(*c*)	7,233	59,490	3,966	9.254 (gossan flux)	1,61,070(*h*)	10,738	83,675	5,578
						425 (secondaries)	1,24,254(*i*)	8,284	1,73,025	11,535
Southern Shan States.	146·8	25,122	1,675	..	..	117·05	4,865	324	..	..
Central Provinces—										
Drug . .	..	..	..	..	..	3	450	30	..	..
Mysore—										
Chitaldrug .	·09	(*d*)	..	..	..	·03	(*j*)	..	..	..
Total .	**71,633·89**	*59,62,172*	*397,478*	*35,56,253(e)*	*237,083*	**62,520·08**	*67,57,157*	*450,477*	*44,33,881(k)*	*295,592*

(*a*) Value of 15,051·85 tons of lead extracted.
(*b*) Value of 1,600·56 tons of lead extracted.
(*c*) Value of 309·72 tons of lead extracted.
(*d*) Value not returned.
(*e*) Value of 1,580,557 ozs. of silver extracted.

(*f*) Value of 17,507·34 tons of lead extracted.
(*g*) Value of 760·18 tons of lead extracted.
(*h*) Value of 455·30 tons of lead extracted.
(*i*) Value of 351·03 tons of lead extracted.
(*j*) Value not returned.
(*k*) Value of 1,970,614 ozs. of silver extracted.

Magnesite.

The sudden demand for Indian magnesite, which arose during the war owing to the temporary loss of Styrian supplies, ceased during the year under review and the Salem output fell from over 18,000 tons in 1917 to a little under 6,000 tons.

TABLE 14.—*Quantity and value of Magnesite produced in India during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Madras—						
Salem . .	18,192	2,18,304	14,554	5,773	69,276	4,618
Mysore . .	10	80	5	80	342	23
Total .	**18,202**	*2,18,384*	*14,559*	**5,853**	*69,618*	*4,641*

Manganese.

The output of manganese-ore fell from about 591,000 tons in 1917 to about 518,000 tons in the year under review. As usual, over 80 per cent. of the production came from the Central Provinces. The amount exported was about 351,000 tons and considerable stocks were held in this country at the end of the year.

TABLE 15.—*Export of Manganese-ore during 1917 and 1918.*

—	1917.		1918.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
To—				
United Kingdom . .	354,276	431,303	251,005	326,658
France	49,971	59,952	46,400	63,867
Italy	19,050	24,629	1,900	2,090
Japan	12,825	26,892	24,545	43,507
United States of America .	45,501	60,591	27,100	45,216
Other Countries . . .	...	...	...	...
Total .	**481,623**	*603,367*	**350,950**	*481,338*

TABLE 16.—*Quantity and value of Manganese-ore produced during 1917 and 1918.*

	1917.		1918.	
	Quantity.	Value f.o.b. at Indian ports.	Quantity.	Value f. o. b. at Indian ports.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Singhbhum . . .	126	292	450	1,170
Gangpur . . .	11,780	27,290	15,895	41,327
Bombay—				
Chota Udepur . .	417	966	7,202	18,725
Panch Mahals . .	26,690	61,832	30,893	80,322
Central Provinces—				
Balaghat . . .	260,706	686,526	214,972	634,167
Bhandara . . .	44,997	118,492	32,245	95,123
Chhindwara . . .	66,235	174,419	72,398	213,574
Jubbulpore . . .	300	790	65	192
Nagpur	145,603	383,421	118,948	350,897
Madras—				
Vizagapatam . . .	1,682	1,864	2,230	3,382
Mysore	32,277	45,188	22,655	42,856
Total .	**590,813**	*1,501,080*	**517,953**	*1,481,735*

Mica.

The urgent demand for mica in all the allied countries resulted in an increase of over 30 per cent. in the declared output which rose from 41,000 cwt. in the year 1917 to nearly 55,000 cwt. in the year under review. As usual, the exports considerably exceeded the recorded production and amounted to 60,075 cwt. valued at £625,741. This figure is less by 2,359 cwt. than the exports of the year 1917.

TABLE 17.—*Quantity and value of Mica produced in India during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Cwts.	Rs.	£	Cwts.	Rs.	£
Bihar and Orissa	34,137	13,77,379	91,825·3	45,607·5	18,60,714	124,047·6
Central India (Gwalior State).	...	...	...	290·2	(*a*)	...
Madras . .	6,050·4	6,85,770	45,718	6,544·7	4,61,593	30,772·9
Mysore . .	...	...	...	17·9	781	52
Rajputana .	720·2	60,923	4,061·5	2,223·8	54,972	3,664·8
Total .	40,907·6	*21,24,072*	*141,604·8*	54,684·1	*23,78,060*	*158,537·3*

(*a*) Value not returned.

Monazite.

There was a slight increase in the output of monazite in Travancore, which rose from 1,940·3 tons, valued at £56,489, in the year 1917 to 2,117·2 tons, valued at £58,819, in the year under review.

Petroleum.

There was an increase of about 4 million gallons in the output of petroleum, the total production being 286,585,011 gallons. This is still lower by 11 million gallons than the output for the year 1916. The chief increases were over 26 million gallons from the Yenangyaung field, 1⅓ million from Minbu and 2½ million from the Badarpur field in Assam. For the first time the Chindwin field shows an output, amounting to nearly ½ million gallons. The Singu field was responsible for the principal decrease in production, its output having fallen by about 24½ million gallons. There were also falls in the outputs of Yenangyat and of Digboi.

TABLE 18.—*Quantity and value of Petroleum produced in India during 1917 and 1918.*

—	1917.			1918		
	Quantity.	Value.		Quantity.	Value.	
	Gallons.	Rs.	£	Gallons.	Rs.	£
Burma—						
Akyab	10,894	3,145	210	10,821	3,122	208
Kyaukpyu	46,821	21,127	1,408	46,598	22,305	1,487
Yenangyaung Field.	176,970,020	1,02,18,182	681,212	203,638,043	1,17,57,392	783,826
Singu Field	85,639,166	49,44,530	329,635	61,035,972	35,24,016	234,934
Yenangyat Field	6,620,908	3,72,370	24,825	4,739,587	2,63,310	17,554
Minbu	3,468,382	2,16,774	14,452	4,826,735	6,03,342	40,223
Thayetmyo	30,000	3,800	253	63,000	7,900	527
Upper Chindwin	..	..	..	473,800	35,535	2,369
Assam—						
Digboi (Lakhimpur).	6,419,840	3,17,648	21,177	5,425,580	2,68,453	17,897
Badarpur	2,924,975	2,19,372	14,625	5,574,068	4,18,055	27,870
Punjab—						
Attock	618,598	77,324	5,155	750,000	75,000	5,000
Mianwali	919	201	13	807	129	9
Total	**282,759,523**	*1,63,94,473*	*1,092,965*	**286,585,011**	*1,69,78,559*	*1,131,904*

The imports of kerosene oil decreased by over 30 per cent. and amounted to only 21,768,176 gallons valued at £1,088,681. The exports of paraffin wax rose from 438,888 cwt., valued at £669,471, in the year 1917 to 508,964 cwt., valued at £775,979, in the year under review.

TABLE 19.—*Imports of Kerosene Oil during 1917 and 1918.*

—	1917.		1918.	
	Quantity.	Value.	Quantity.	Value.
	Gallons.	£	Gallons.	£
From—				
Borneo	260,718	10,419	...	...
Persia	4,294,068	163,241	8,193,438	315,946
Straits Settlements (including Labuan).	1,641	48	...	...
United States of America	28,781,796	1,104,891	13,574,515	772,719
Other Countries	9,999	583	223	16
Total	**33,348,222**	*1,279,182*	**21,768,176**	*1,088,681*

TABLE 20.—*Exports of Paraffin Wax from India during 1917 and 1918.*

—	1917.		1918.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
To—				
United Kingdom	112,308	169,534	103,680	157,099
China	24,304	36,490	12,592	28,818
Japan	78,868	123,468	88,520	134,255
Egypt	45,640	72,465	46,950	71,223
United States of America	24,247	36,775	14,000	21,233
Australia (including New Zealand).	53,480	81,414	61,441	93,209
Other Countries	100,041	149,325	181,772	270,142
Total	**438,888**	*669,471*	**508,964**	*775,979*

Platinum.

Owing to the cessation of the gold-dredging operations at Myitkyina, Burma has ceased to produce platinum, the quantity recovered during the year 1918 being only 0·31 oz.

Ruby, Sapphire and Spinel.

There was a considerable fall in the output of the Ruby Mines, the total production being only 164,115 carats valued at £40,310.

TABLE 21.—*Quantity and value of Ruby, Sapphire and Spinel produced in India during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Carats.	Rs.	£	Carats.	Rs.	£
Burma—						
Mogok	132,409 (Rubies)	6,53,622	43,575	1,01,637 (Rubies)	5,17,367	40,310
	32,369 (Sapphires)	1,20,255	8,017	34,949 (Sapphires)	83,571	
	33,422 (Spinel)	3,590	239	27,529 (Spinel)	3,711	
Total	**198,200**	*7,77,467*	*51,831*	**164,115**	*6,04,649*	*40,310*

Salt.

There was a large increase in the output of salt, which rose from a little over 1,427,000 tons in 1917 to nearly 2 million tons in the year under review. The chief increases were 200,000 tons in Madras and 167,000 tons in Northern India. Imports rose from 342,000 tons in 1917 to over 388,000 tons in the year under review, more than half of the total imports being from Egypt.

TABLE 22.—*Quantity and value of Salt produced in India during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Aden . .	122,926	9,89,286	65,952	142,076	14,78,078	98,538
Bengal . .	21	422	28	30	582	39
Bombay and Sind	457,989	24,68,193	164,546	481,812	55,92,452	372,830
Burma . .	43,650	34,48,226	229,882	62,828	51,60,774	344,052
Central India .	25·1	1,710	114	5·3	362	24
Gwalior State .	269	12,803	854	312	14,864	991
Madras . .	394,985	57,69,261	384,617	596,676	92,62,352	617,490
Northern India .	405,731	20,53,753	136,917	572,672	31,53,660	210,244
Rajputana .	2,057	3,704	247	29·1	50	3
Total .	**1,427,653·1**	*1,47,47,358*	*983,157*	**1,856,440·4**	*2,46,63,174*	*1,644,211*

TABLE 23.—*Quantity and value of Rock-Salt produced in India during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Salt Range .	152,351	3,88,810	25,920·7	159,498	4,07,049	27,136·6
Kohat . .	23,787	37,638	2,509·2	21,260	37,215	2,481
Mandi . .	4,829	86,276	5,751·7	5,085	90,834	6,055·6
Total .	**180,967**	**5,12,724**	**34,181·6**	**185,843**	**5,35,098**	**35,673·2**

TABLE 24.—*Quantity and Value of Salt imported into India during 1917 and 1918.*

From	1917.		1918.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
United Kingdom . . .	33,071	157,347	19,233	94,513
Spain	36,304	156,175	38,305	172,088
Aden and Dependencies .	114,454	458,667	94,061	385,502
Egypt	116,706	418,309	203,662	821,832
Italian East Africa . .	41,419	169,249	33,085	123,990
Other Countries . . .	32	346	213	1,357
Total .	**341,986**	*1,360,093*	**388,559**	*1,599,282*

Saltpetre.

There was a slight rise in the total production of saltpetre due chiefly to an increase of over 60 per cent. in the production of the United Provinces. The output of the Punjab fell by about 25 per cent. The total Indian production amounted to 24,741 tons valued at Rs. 88,37,855 (£589,190). Exports fell from 26,000 tons in 1917 to 23,000 tons in the year under review. The exports to the United Kingdom fell from 24,000 tons to 17,000 tons, while those of the United States increased from 150 tons to 5,500 tons.

TABLE 25.—*Quantity and Value of Saltpetre produced in India during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar . .	5,024·3	18,44,923	122,995	6,299·3	23,13,103	154,207
Central India .	28·9	3,783	252	26·2	2,698	180
Punjab . .	9,141	34,01,890	226,793	6,946·7	19,84,956	132,330
Rajputana .	234·2	1,03,391	6,893	245	80,290	5,353
United Provinces	6,855·4	25,61,006	170,733	11,223·6	44,56,808	297,120
Total .	**21,283·8**	*79,14,993*	*527,666*	**24,740·8**	*88,37,865*	*589,190*

TABLE 26.—*Distribution of Saltpetre exported during 1917 and 1918.*

	1917.		1918.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
Ceylon	1,051	1,398	...	...
Japan	8,037	9,590	11,968	14,776
Mauritius and Dependencies .	11,095	14,453	...	...
United Kingdom . . .	479,194	630,475	336,828	445,024
United States of America . .	3,000	3,966	110,067	141,947
Other Countries . . .	14,997	20,141	8,717	11,908
Total .	517,374	*680,023*	467,580	*613,655*

Silver.

The output of silver from Bawdwin has already been shown under lead. In addition to this a small quantity, amounting to 1,169 oz., was produced from the Anantapur gold mine in Madras. The total Indian production of silver was 1,971,783 oz., valued at Rs. 44,35,441 (£295,696).

Tin.

There was a small increase in the output of tin-ore, which rose from 13,321 cwt. in 1917 to 15,607 cwt. in the year under review. The whole of the ore was produced in Lower Burma and nearly half of it in the Southern Shan States. Mergui also produced 2,000 cwt. of block tin. The imports of tin fell from 28,180 cwt. in 1917 to 24,596 cwt. in the year under review. Practically the whole of the tin imported came from the Straits Settlements.

TABLE 27.—*Quantity and Value of Tin and Tin-ore for the years 1917 and 1918.*

	1917.						1918					
	BLOCK TIN.			TIN-ORE.			BLOCK TIN.			TIN-ORE.		
	Quantity.	Value.		Quantity.	Value.		Quantity.	Value.		Quantity.	Value.	
	Cwt.	Rs.	£	Cwt.	Rs.	£	Cwt.	Rs.	£	Cwt.	Rs.	£
Burma—												
Amherst . .	..	..	..	33	2,640	176	..	..	..	1,317·5	1,31,500	8,767
Mergui . .	2,817·9	4.19,433	27,962	1,761	1,63,945	10,930	2,013·6	4.21,854	28,123	1,471·2	1,86,483	12,432
Southern Shan States.	..	..	..	8,083	6,06,600	40,440	..	..	..	7,609	7,70,415	51,361
Tavoy . .	..	..	..	1,762	1,65,236	11,016	..	..	..	4,052·7	4,65,837	31,056
Thaton . .	..	..	..	1,677	59,573	3,971	..	..	..	1,157	43,440	2,896
Total .	**2,817·9**	*4,19,433*	*27,962*	**13,321**	*9,97,994*	*66,533*	**2,013·6**	*4,21,854*	*28,123*	**15,607·4**	*15,97.675*	*106,512*

TABLE 28.—*Imports of Tin unwrought (blocks, ingots, bars and slabs) into India during 1917 and 1918.*

—	1917.		1918.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
From—				
United Kingdom . .	934	10,279	289	3,993
Straits Settlements (including Labuan).	26,339	272,805	23,833	323,860
Other Countries . .	907	9,051	474	4,869
Total .	**28,180**	*292,135*	**24,596**	*332,722*

Tungsten.

There was a slight decrease in the output of wolfram, which fell from 4,542 tons in 1917 to 4,431 tons in the year under review. As usual, most of the output came from Tavoy.

TABLE 29.—*Quantity and Value of Tungsten-ore produced in India during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar and Orissa—						
Singhbhum .	20	20,000	1,333	2·5	7,465	498
Burma—						
Kyaukse .	...	...	...	·1	250	17
Mergui . .	368	7,4[illegible],114	49,541	376·6	7,87,359	52,490
Southern Shan States.	307	5,98,650	39,910	287	6,24,225	41,615
Tavoy . .	3,697·5	76,31,906	508,794	3,636·1	91,62,490	610,833
Thaton . .	107·5	2,30,492	15,366	91·5	2,04,945	13,663
Rajputana—						
Marwar .	42	1,21,950	8,130	37·4	1,08,079	7,205
Total .	**4,542**	*93,46,112*	*623,074*	**4,431·2**	*1,08,94,813*	*726,321*

III.—MINERALS OF GROUP II.

Agate. For the first time for many years, the agate industry in Rajpipla was suspended. It is hoped, however, that, with the resumption of trade with the Continent of Europe, this industry may revive.

Alum. The production of alum fell from 5,434 cwt. in 1917 to 1,322 cwt. valued at Rs. 14,400 (£960) in the year under review. The whole output came from the Mianwali district of the Punjab.

Amber. The production of amber in Burma fell from 59·1 cwt. in 1917 to 2·9 cwt. valued at Rs. 1,300 (£87) in the year under review.

Antimony. No antimony ore was produced during the year.

Apatite. Prospecting operations resulted in the production of 5,100 tons of apatite from the apatite-magnetite deposits of Singhbhum. The estimated value of the production was Rs. 51,000 (£3,400).

Aquamarine. The output of aquamarine in Kashmir was valued at Rs. 2,700.

Asbestos. There was a rise in the output of asbestos from 148 tons in 1917 to 357 tons valued at Rs. 14,468 (£965) in the year under review. Of this 344 tons were won in the Hassan district of Mysore and 13 tons in the Bhandara district of the Central Provinces.

Barytes. 2,724 tons of barytes valued at Rs. 44,215 (£2,948) were produced in the Karnul district of the Madras Presidency.

Bauxite. There was a decrease of 171 tons in the output of bauxite, which amounted to 1,192 tons valued at Rs. 13,410 (£894). The whole output came from Jubbulpore.

TABLE 30.—*Production of Building Materials and Road Metal in India during the year 1918.*

—	GRANITE.		LATERITE.		LIME.		LIMESTONE AND KANKAR.		MARBLE.		SANDSTONE.		SLATE.		TRAP.		MISCELLANEOUS.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£
Assam	..	..	..	..	..	..	58,928	3,920	..	..	..	..	..	..	..	..	..	..
Bihar and Orissa.	20,205	1,318	1,629	680	256	7	335,627	49,256	..	..	97,134	2,955	1,821	1,878	5,771	425	267,722	9,360
Bombay	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Burma	182,892	15,760	162,428	10,844	..	..	199,222	15,782	..	..	79,166	4,247	..	..	..	..	391,899	22,070
Central India	..	..	..	..	26,183	14,809	77,493	4,749	..	..	..	..	..	..	..	..	1,990	47
Central Provinces.	..	..	..	..	..	..	134,798	12,479	..	..	..	..	..	..	..	..	..	..
Hyderabad	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Madras	116,296	4,518	110,515	5,048	..	..	6,028	502	..	..	..	..	..	..	..	..	77,350	5,974
North-West Frontier Province.	..	..	..	..	..	..	8,072	363	..	..	..	..	..	..	..	..	..	..
Punjab	..	..	..	..	..	..	40,046	1,914	..	..	27,613	1,563	8,114	9,122	..	..	10,284	160
Rajputana	..	..	..	..	..	..	815	480	3,896	230	33,937	11,473	..	..	..	..	48,384	3,321
United Provinces.	..	..	..	..	242	78	3 851	696	..	..	6,000	2,800	27,676	352	..	..	145,026	19,170
Total	**319,393**	*21,596*	**274,572**	*16,572*	**26,681**	*14,894*	**864,880**	*90,141*	**3,896**	*230*	**243,850**	*23,043*	**37,611**	*11,352*	**5,771**	*425*	**942,655**	*60,102*

Building Materials.

The total estimated value of building-stone and road-metal produced during the year 1918 was Rs. 35,75,322 (£238,355).

Clay.

The recorded production of clay was 143,223 tons valued at Rs. 2,04,349 (£13,623).

Corundum.

There was a slight decrease in the output of corundum from a little over 41,000 cwt. in 1917 to 40,281 cwt. in the year under review.

TABLE 31.—*Quantity and value of corundum produced during the years 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Cwt	Rs.	£	Cwt.	Rs.	£
Assam—						
Khasi and Jaintia Hills.	41,200	56,992	3,799·5	37,920	57,930	3,862
Central India—						
Rewah State .	200	977	65·1	736	3,022	201·5
Central Provinces						
Bhandara .	...	...	...	1,600	490	32·7
Madras—						
South Canara	25·8	155	10·3	25	151	10
Total .	**41,425·8**	*58,124*	*3,874·9*	**40,281**	*61,593*	*4,106·2*

Gypsum.

The production of gypsum was stationary, the total output being 16,746 tons valued at Rs. 17,094 (£1,139).

TABLE 32.—*Production of Gypsum during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Punjab—						
Jhelum . .	1,068	801	53·4	1,871	1,403	93·5
Rajputana—						
Bikaner .	8,116	9,922	661·4	8,469	11,576	771·7
Marwar .	7,499	4,800	320	6,406	4,115	274·3
Total .	**16,683**	*15,523*	*1,034·8*	**16,746**	*17,094*	*1,139·5*

Molybdenite. Only 4 cwt. of molybdenite, valued at Rs. 924 (£62), were won during the year 1918; this amount was recovered in the course of wolfram mining operations in Tavoy.

Ochre. The output of ochre fell considerably but there was a large increase in its value owing to a great appreciation of the price of the production from one of the small states in Central India.

TABLE 33.—*Production of Ochre during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar and Orissa	69	730	49	145	9,589	639
Central India .	2,174	11,589	772	736	18,910	1,261
Central Provinces	900	12,118	808	16	5	...
Mysore . .	...	...	...	74	888	59
Total .	**3,143**	*24,437*	*1,629*	**971**	*29,392*	*1,959*

Potash Salts. 135 tons of potash salts were produced by the Northern India Salt Revenue Department at Nurpur in the Salt Range. The pit's-mouth value of the output is stated to be Rs. 687 (£46).

Samarskite. 1½ cwt. of samarskite valued at Rs. 67 was won from the Sankara mica mine in Nellore.

Steatite. There was again an increase, amounting to over 60 per cent., in the output of steatite which rose from 7,829 tons in 1917 to 12,983 tons, valued at Rs. 1,63,818 (£10,921), during the year under review.

TABLE 34.—*Quantity and value of Steatite produced in India during 1917 and 1918.*

—	1917.			1918.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar and Orissa—						
Mayurbhanj .	50	4,000	267	40	3,500	233
Burma—						
Meiktila .	4,846	17,959	1,197	8,428	47,761	3,184
Myingyan .	16	375	25	17	431	29
Central India—						
Bijawar .	73·3	5,794	386	...	...	...
Central Provinces—						
Jubbulpore .	2,421·8	39,295	2,620	3,492·8	61,038	4,069
Madras—						
Bellary . .	23	115	8	44·5	220	15
Kurnul . .	10·3	1,726	115	10·1	1,650	110
Nellore . .	19·5	1,155	77	51	3,272	218
Salem . .	149·6	11,430	762	642·8	13,630	909
Mysore . .	8·5	256	17	·1	5	...
Rajputana—						
Ajmer-Merwara	119·7	4,776	318	...	...	...
United Provinces—						
Hamirpur .	80	9,450	630	247	31,661	2,111
Jhansi . .	11	715	48	10	650	43
Total .	*7,828·7*	*97,046*	*6,470*	**12,983·3**	*1,63,818*	*10,921*

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 35.—*Statement of Mineral Concessions granted during 1918.*

ASSAM.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Cachar .	(1) Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. .	5,056	4th March 1918.	1 year.
Do. .	(2) The Burma Oil Co., Ltd.	Do. . .	P. L. .	4,409·6	12th April 1918.	Do.
Do. .	(3) Do. . .	Do. . .	P. L. .	6,169·6	8th April 1918.	Do.
Do. .	(4) Do. . .	Do. . .	P. L. .	6,784	Do	Do.
Do. .	(5) The Badarpur Oil Co., Ltd.	Do. . .	P. L. .	3,308·8	21st September 1918.	Do.
Do. .	(6) The Burma Oil Co., Ltd.	Do. . .	P. L. .	1,088	28th October 1918.	Do.
Sylhet .	(7) Do. . .	Do. . .	P. L. .	3,136	30th December 1918.	Do.

BALUCHISTAN.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bolan Pass.	(8) Mr. Tikamdas Girdhari Das of Shikarpur.	Coal and coal dust	M. L. .	244	1st January 1918.	30 years.
Kalat .	(9) The Burma Oil Co., Ltd. of Rangoon.	Oil . . .	P. L. .	24,960	18th December 1917.	1 year.
Do. .	(10) The Indo-Burma Petroleum Co., Ltd., Rangoon, through their Managing Agents Messrs. Steel Brothers & Co.	Do. . . .	P. L. .	15,360	20th May 1918	Do.
Do. .	(11) Do. . .	Do. . . .	P. L. .	17,920	Do. .	Do

BIHAR AND ORISSA.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Hazaribagh	(12) Babu Nagendra Nath Samanta.	Mica . . .	P. L. .	400	19th February 1918.	1 year.
Do. .	(13) Babu Bhim Ram Mahuri.	Do. . . .	P. L. .	120	22nd February 1918.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BIHAR AND ORISSA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Hazaribagh	(14) Babu Malloo Khan	Mica . .	P. L. .	120	13th February 1918.	1 year.
Do. .	(15) Babu Probodh Chandra Mukharji.	Do. . . .	P. L. .	120	7th February 1918.	Do.
Do. .	(16) The Mica Mining and Manufacturing Co., Ltd.	Do. . . .	P. L. .	89·2	25th February 1918.	Do.
Do. .	(17) Babu Raghubir Roy	Do. . . .	P. L. .	160	15th April 1918.	Do.
Do. .	(18) Babu Bhujendra Nath Daw.	Do. . . .	P. L. .	320	1st April 1918.	Do.
Do. .	(19) Babu Kiran Sashi Chatterji.	Do. . . .	P. L. .	160	15th April 1918.	Do.
Do. .	(20) Babu Banka Behary Chaudhury.	Do. . . .	P. L. .	221	28th June 1918.	Do.
Do. .	(21) Babu Chattoo Ram	Do. . . .	P. L. .	160	8th March 1918.	Do.
Do. .	(22) Mr. J. W. Martin .	Do. . . .	P. L. .	195	1st March 1918.	Do.
Do. .	(23) Babu Dwijendra Nath Mukharji.	Do. . . .	M. L. .	212	19th March 1918.	30 years.
Do. .	(24) Babu Probodh Chandra Mukharji.	Do. . . .	M. L. .	80	5th October 1917.	Do.
Do. .	(25) Babu Rekhabchand Doogar.	Do. . . .	M. L. .	4·05	9th October 1917.	Do.
Do. .	(26) Messrs. Tata Sons & Co.	Do. . . .	M. L. .	40	29th November 1917.	Do.
Do. .	(27) Mr. G. H. Fairhurst	Manganese and iron.	P. L. .	153·6	Not stated .	1 year.
Do. .	(28) The Indian Iron and Steel Co., Ltd.	Do. . . .	P. L. .	1,245·76	Do. .	Do.
Do. .	(29) Messrs. Bird & Co.	General license .	P. L. .	26,240	Do.	Do.
Palamau .	(30) Babu Pran Krishna Chatterji.	Graphite . .	P. L. .	640	29th June 1918.	Do.
Santal Parganas.	(31) Babu Baidya Nath De.	Coal . . .	P. L. (renewal.)	10·15	1st April 1918	Do.
Do. .	(32) Babu Benode Behary De.	Do. . . .	P. L. (renewal.)	2·15	Do. .	Do.
Do. .	(33) Babu Jamuna Prasad Marwari.	Do. . . .	P. L. (renewal.)	2·60	1st May 1918	Up to 31st March 1919.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BIHAR AND ORISSA—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Santal Parganas.	(34) Babu Bansi Ram Marwari.	Coal . . .	P. L. (renewal.)	1·90	1st May 1918	Up to 31st March 1919.
Do. .	(35) Do. . .	Do. . . .	P. L. (renewal.)	0·33	Do. .	Do.
Singhbhum	(36) Mr. G. L. Sidey .	Gold . . .	P. L. .	2,120	Not stated .	1 year.
Do. .	(37) Babu Moti Lal Iswardar.	Manganese . .	P. L. .	613·18	13th January 1918.	Do.
Do. .	(38) Babu Ajit Kumar Mallick.	Yellow ochre .	P. L. (renewal.)	11·90	8th January 1918.	Do.
Do. .	(39) Babu Mangi Lal Marwari.	Manganese . .	P. L. .	106·20	4th February 1918.	Do.
Do. .	(40) The Bengal Iron and Steel Co., Ltd.	Manganese and iron.	P. L. (renewal.)	992	21st December 1917.	Do.
Do. .	(41) Babu N. N. Goswami	Yellow ochre .	M. L. .	34·59	Not stated .	10 years.
Do. .	(42) Do. . .	Chromite . .	M. L. .	143·66	Do. .	30 years.
Do. .	(43) Do. . .	Manganese . .	M. L. .	573	Do. .	Do.
Do. .	(44) Messrs. Burn & Co.	Iron and manganese.	M. L. .	3,571·20	Do. .	Do.
Do. .	(45) Do. . .	Do. . .	M. L. .	1,510·40	Do. .	Do.
Do. .	(46) Babu N. N. Goswami.	Yellow ochre .	M. L. .	34·59	Do. .	10 years.
Do. .	(47) The Tata Iron and Steel Co., Ltd.	Iron . . .	P. L. .	4,761·6	Do. .	1 year.
Do. .	(48) The Bengal Iron and Steel Co., Ltd.	Manganese and iron.	P. L. .	704	Do. .	Do.
Do. .	(49) Mr. A. C. Maitra .	Gold . . .	M. L. .	150	Do. .	20 years.
Do. .	(50) Messrs. Rae & Co. .	Chromite . .	P. L. .	1,600	Do. .	1 year.
Do. .	(51) The Indian Iron and Steel Co., Ltd.	Iron and manganese.	P. L. .	832	Do. .	Do.
Do. .	(52) The Tata Iron and Steel Co., Ltd.	Do. . .	P. L. .	3,776	Do. .	Do.
Do. .	(53) Messrs. Burn & Co.	Do. . .	M. L. .	96	Do. .	30 years.

BOMBAY.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Belgaum .	(54) Messrs. Tata & Sons, Bombay.	Bauxite (aluminium ore).	P. L. .	1,087·4	23rd May 1918.	1 year.
Dharwar .	(55) Mr. L. C. Oliver .	Galena . .	P. L. (renewal.)	1,143	18th June 1918.	Do.

P. L. = *Prospecting Licence.* M. L. = *Mining Lease.*

BOMBAY—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kaira . .	(56) Shivrajpur Syndicate, Ltd.	Manganese and aluminium.	P. L. .	391·95	2nd July 1918.	1 year.
Sukkur .	(57) The Managing Agents, Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. .	6,008	20th August 1918.	Do.

BURMA.

Akyab .	(58) Messrs. The Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. .	1,280	22nd April 1918.	1 year.
Amherst .	(59) L. Gwan Shein .	All minerals (except oil).	P. L. .	640	21st January 1918.	Do.
Do. .	(60) Maung Tarok .	Do. . .	P. L. .	1,280	20th April 1918.	Do.
Do. .	(61) Do. . .	Do. . .	P. L. .	640	1st May 1918	Do.
Do. .	(62) Do. . .	Do. . .	P. L. .	640	20th April 1918.	Do.
Do. .	(63) Maung Ba Si .	Do. . .	P. L. .	1,824	30th April 1918.	Do.
Do. .	(64) Maung San Ye .	Do. . .	P. L. .	425	25th June 1918.	Do.
Do. .	(65) Lim Htain Whet .	Do. . .	P. L. .	1,100	22nd May 1918.	Do.
Do. .	(66) Maung San Ye .	Do. . .	P. L. .	560	3rd April 1918.	Do.
Do. .	(67) Maung Myat Hein .	Do. . .	P. L. .	640	23rd April 1918.	Do.
Do. .	(68) Mrs. M. M. Hla Oung.	Do. . .	P. L. .	850	27th May 1918.	Do.
Do. .	(69) Maung Myat Hein .	Do. . .	P. L. .	640	23rd April 1918.	Do.
Do. .	(70) Ma Thein Yin .	Do. . .	P. L. .	640	7th June 1918.	Do.
Do. .	(71) Maung Tun Hla .	Do. . .	P. L. .	640	20th May 1918.	Do.
Do. .	(72) Dr. K. S. Kanga .	Do. . .	P. L. .	160	29th June 1918.	Do.
Do. .	(73) Mr. H. E. Singleton	Do. . .	P. L. (renewal.)	319	27th March 1917.	2 years.

P. L. = *Prospecting License.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Amherst .	(74) Ma Thein Yin .	All minerals (except oil).	P. L. .	682	26th September 1918.	1 year.
Do. .	(75) Mr. M. Shawloo .	Do. . .	P. L. .	640	31st July 1918.	Do.
Do. .	(76) Ma Thein Yin .	Do. . .	P. L. .	319	26th September 1918.	Do.
Do. .	(77) Maung Thoung Pe .	Do. . .	P. L. .	160	20th August 1918.	Do.
Do. .	(78) Ma Thein Yin .	Do. . .	P. L. .	960	26th September 1918.	Do.
Do. .	(79) L. Gwan Shein .	Do. . .	P. L. (renewal.)	1,088	20th April 1918.	2 years.
Do. .	(80) Ma Chein . .	Do. . .	P. L. .	640	15th July 1918.	1 year.
Do. .	(81) Messrs. T. D. Findlay & Son.	Do. . .	P. L. .	1,280	8th September 1918.	Do.
Do. .	(82) Maung Myat Hein and three others.	Do. . .	P. L. .	213·3	14th November 1918.	Do.
Do. .	(83) Mr. V. Palmgren .	Do. . .	P. L. .	1,280	7th September 1918.	Do.
Do. .	(84) Dr. M. Shawloo .	Do. . .	P. L. .	819·2	12th July 1918.	Do.
Do. .	(85) Mr. F. A. Boog and two others.	Do. . .	P. L. .	737·28	1st August 1918.	Do.
Do. .	(86) Maung Ba Lin .	Do. . .	P. L. .	640	23rd December 1918.	Do.
Do. .	(87) L. Ah Choy . .	Do. . .	P. L. .	640	14th October 1918.	Do.
Do. .	(88) K. P. N. K. Narainan Chetty.	Do. . .	P. L. .	640	13th December 1918.	Do.
Do. .	(89) Ma Shwe Bwa .	Do. . .	P. L. .	320	19th December 1918.	Do.
Do. .	(90) D. Gwan Shein .	Do. . .	P. L. .	640	Do. .	Do.
Do. .	(91) Mr. W. Lonsdale .	Do. . .	P. L. .	640	Do. .	Do.
Do. .	(92) L. Ah Ngoon .	Do. . .	P. L. .	640	20th December 1918.	Do.
Henzada	(93) Mr. L. D'Attaides .	Do. . .	P. L. .	4,736	11th May 1918.	Do.
Do. .	(94) Li Shai Lone . .	Coal . . .	P. L. .	1,006·5	25th May 1918.	Do.
Do.	(95) Mr. L. D'Attaides .	All minerals (except oil).	P. L. .	499·52	20th May 1918.	Do.
Katha	(96) Maung Aung . .	Gold . . .	P. L. .	2,752	9th January 1918.	Do.

P. L.=*Prospecting License.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Katha .	(97) Mr. R. E. Smith .	All minerals (except oil).	P. L. .	3,200	16th April 1918.	1 year.
Do. .	(98) Maung Kyi . .	Wolfram, silver, tin, gold, copper and zinc.	P. L. .	1,331·20	26th July 1918.	Do.
Do. .	(99) Messrs. J. A. Begbie & Co.	Gold, copper, iron, silver, lead and wolfram.	P. L. .	3,200	13th August 1918.	Do.
Do. .	(100) Maung Kyi . .	All minerals (except oil).	P. L. .	1,170·40	26th July 1918.	Do.
Kyaukse .	(101) Messrs. Jamal Bros. & Co., Ltd.	Do. . .	P. L. .	2,733	28th September 1918.	Do.
Do. .	(102) Saw Lein Lee .	Do. . .	P. L. (renewal.)	1,800·16	30th May 1918.	2 years.
Lower Chindwin.	(103) Mr. A. K. A. S. Jamal.	Do. . .	P. L. .	1,680	23rd March 1918.	1 year.
Do. .	(104) Messrs. Jamal Bros. & Co., Ltd.	Do. . .	P. L. .	140	Do. .	Do.
Do. .	(105) Do. . .	Do. . .	P. L. .	1,120	Do. .	Do.
Do. .	(106) Messrs. The Burma Oil Co., Ltd.	Mineral oil . .	P. L. . (renewal.)	640	15th August 1918.	2 years.
Magwe .	(107) Mr. S. E. Solomon	Do. . .	P. L. .	208·1	21st February 1918.	1 year.
Do. .	(108) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. .	3,840	23rd March 1918.	Do.
Do. .	(109) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. . (renewal.)	2,560 Blocks Nos. 3S, 4S, 5S and 6S of the Yenangyaung oil-field.	1st December 1917.	2 years.
Do. .	(110) Messrs. The Burma Oil Co., Ltd.	Do. . .	M. L. .	1,764·4	1st November 1917.	30 years.
Do. .	(111) Do. . .	Do. . .	P. L. .	2,259·2	25th June 1918.	1 year.
Mandalay .	(112) Mr. A. A. S. Jamal	All minerals (except oil).	P. L. .	5,120	23rd February 1918.	Do.
Do. .	(113) Do. . .	Do. . .	P. L. .	5,120	7th June 1918.	Do.
Mergui .	(114) Mr. J. F. Leslie .	Do. . .	P. L. .	220·16	20th February 1918.	Do.
Do. .	(115) Maung Kyin Bu .	Tin	P. L. .	349·44	4th February 1918.	Do.
Do. .	(116) Mr. A. S. Mahomed	All minerals (except oil).	P. L. .	550·64	Do. .	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(117) Maung Pe Kin .	All minerals (except oil).	P. L. .	250·88	4th February 1918.	1 year.
Do. .	(118) Mr. J. F. Leslie .	Do. . .	P. L. .	512	25th February 1918.	Do.
Do. .	(119) Mrs. M. La Bouchadiere.	Do. . .	P. L. (renewal.)	635·26	24th March 1917.	Do.
Do. .	(120) Mr. Hand and Akbar Shah.	Do. . .	P. L. (renewal.)	3,200	19th December 1917.	Do.
Do. .	(121) Mr. A. S. Mahomed	Do. . .	P. L. (renewal.)	1,013·76	4th January 1918.	Do.
Do. .	(122) Yew Shwe Ni .	Do. . .	P. L. (renewal.)	1,149	28th January 1918.	Do.
Do. .	(123) Maung Pan On .	Do. . .	P. L. (renewal.)	153·60	19th March 1918.	Do.
Do. .	(124) Maung Pe Thaik .	Tin and wolfram .	P. L. (renewal.)	486·40	12th February 1918.	Do.
Do. .	(125) M. Haniff . .	All minerals (except oil).	P. L. (renewal.)	350·72	24th March 1918.	Do.
Do. .	(126) Maung Po . .	Wolfram and tin .	P. L. .	640	21st June 1918.	Do.
Do. .	(127) Lim Shain . .	Do. . .	P. L. .	256	20th May 1918.	Do.
Do. .	(128) Maung Shwe Thi .	All minerals (except oil).	P. L. (renewal.)	852·48	15th February 1918.	Do.
Do. .	(129) Yew Shwe Ni .	Wolfram and tin .	P. L. (renewal.)	1,775·52	20th April 1918.	Do.
Do. .	(130) Maung Ngwe Thi .	Do. . .	P. L. (renewal.)	746·52	3rd April 1918	Do.
Do. .	(131) Messrs. Bulloch Bros. & Co., Ltd.	All minerals (except oil).	P. L. .	442·88	1st January 1917.	Do.
Do. .	(132) Maung Ne Gyi .	Do. . .	P. L. .	896	13th September 1918.	Do.
Do. .	(133) Messrs. The Hpaungdaw Prospecting Co., Ltd.	Do. . .	P. L. .	1,400·60	30th July 1918.	Do.
Do. .	(134) Do. . .	Do. .	P. L. .	1,970·52	Do. .	Do.
Do. .	(135) Messrs. Bulloch Bros. & Co., Ltd.	Wolfram and tin .	P. L. .	286·72	1st August 1918.	Do.
Do. .	(136) Mr. A. S. Mahomed	All minerals (except oil).	P. L. .	844·80	13th August 1918.	Do.
Do. .	(137) Mr. A. E. Ahmed .	Do. . .	P. L. .	634·88	Do.	Do.
Do. .	(138) Messrs. Bulloch Bros. & Co., Ltd.	Wolfram and tin .	P. L. .	138·24	Do.	Do.
Do. .	(139) Eu Shwe Swai .	Do. . .	P. L. .	1,566·72	6th July 1918.	Do.

P. L.—*Prospecting License.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(140) Lim Oo Ghine .	Wolfram and tin	P. L. .	512	9th September 1918.	1 year.
Do. .	(141) M. Haniff . .	All minerals (except oil).	P. L. .	1,054·72	30th July 1918.	Do.
Do. .	(142) Messrs. The Rangoon Wolfram Co., Ltd.	Do. . .	P. L. .	1,203·20	9th September 1918.	Do.
Do. .	(143) Lim Shain . .	Do. . .	P. L. .	517·12	16th August 1918.	Do.
Do. .	(144) Do. . .	Do. . .	P. L. .	875·52	Do. .	Do.
Do. .	(145) Do. . .	Tin and wolfram	P. L. .	517·36	Do.	Do.
Do. .	(146) Messrs. The Rangoon Wolfram Co., Ltd.	All minerals (except oil).	P. L. .	332·80	9th September 1918.	Do.
Do. .	(147) Lim Shain . .	Do. . .	P. L. .	450·56	16th August 1918.	Do.
Do. .	(148) Mr. S. O. Holmes .	Tin and tungsten ores.	P. L. .	517·12	27th September 1918.	Do.
Do. .	(149) Mr. H. H. Bateman	Wolfram and tin .	P. L. .	1,824	17th September 1918.	Do.
Do. .	(150) Do. . .	Do. . .	P. L. .	480	27th September 1918.	Do.
Do. .	(151) Do. . .	Wolfram . .	P. L. .	640	Do. .	Do.
Do. .	(152) Maung Po . .	All minerals (except oil).	P. L. (renewal.)	256	23rd December 1917.	Do.
Do. .	(153) Do. . .	Do. . .	P. L. (renewal.)	691·20	3rd April 1918	Do.
Do. .	(154) C. Swee Htin .	Wolfram . .	P. L. (renewal.)	2,626·56	3rd May 1918	Do.
Do. .	(155) Mr. A. H. Noyes .	All minerals (except oil).	P. L. (renewal.)	100	26th November 1917.	Do.
Do. .	(156) Mrs. M. La Bouchediere.	Do. . .	P. L (renewal.)	635·26	25th March 1918.	Do.
Do. .	(157) Messrs. Bulloch Bros. & Co., Ltd.	Do. . .	P. L. (renewal.)	442·88	2nd January 1918.	Do.
Do. .	(158) Tan Po Chit .	Do. . .	P.L. (renewal.)	320	17th September 1918.	Do.
Do. .	(159) Mr. E. Ahmed .	Do. . .	M. L. .	2,896·72	18th August 1915.	30 years.
Do. .	(160) Maung Choon .	Tin and allied minerals.	P. L. .	25·37	22nd November 1918.	1 year.
Do. .	(161) Maung Shwe Don	All minerals (except oil).	P. L. .	796·16	30th October 1918.	Do.
Do. .	(162) Hoe Cheng Keat .	Do. . .	P. L. .	588·80	14th November 1918.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(163) M. Haniff . .	All minerals (except oil).	P. L. .	1,356·8	18th November 1918.	1 year.
Do. .	(164) Maurg E Gyi .	Wolfram and tin .	P. L. .	358·40	5th December 1918.	Do.
Do. .	(165) Maung Choon .	All minerals (except oil).	P. L. .	517·12	11th December 1918.	Do.
Do. .	(166) C. Po Kun . .	Do. . .	P. L. .	747·52	20th December 1918.	Do.
Do. .	(167) Mr. H. H. Bateman	Wolfram and tin .	P. L. .	1,500·16	Do. .	Do.
Do. .	(168) U. Shwe I. . .	All minerals (except oil).	P. L. .	445·44	11th December 1918.	Do.
Do. .	(169) Maung Maung .	Tin	P. L. . (renewal.)	640	2nd November 1918.	Do.
Minbu .	(170) Messrs. The Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. .	1,692	12th January 1918.	Do.
Do. .	(171) Messrs. The British Burma Petroleum Co., Ltd.	Do. . .	P. L. .	336	2nd November 1917.	Do.
Do. .	(172) Do. . .	Do. . .	P. L. .	174	22nd January 1918.	Do.
Do. .	(173) Mahomed Esoof Bhymeah & Co.	Do. . .	P. L. . (renewal.)	320	19th June 1917.	2 years.
Do. .	(174) Messrs. The British Burma Petroleum Co., Ltd.	Do. . .	P. L. . (renewal.)	640	17th August 1917.	1 year.
Do. .	(175) Do. . .	Do. . .	P. L. . (renewal.)	614·4	Do. .	Do.
Do. .	(176) Do. . .	Do. . .	P. L. . (renewal.)	440·32	3rd August 1917.	2 years.
Do. .	(177) Maung Tun Aung Gyaw.	Coal . . .	P. L. .	640	4th April 1918	1 year.
Do. .	(178) Messrs. The British Burma Petroleum Co., Ltd.	Mineral oil . .	M. L. .	320 (Western half of block 188 of the Minbu oil-field.)	5th June 1917.	30 years.
Do. .	(179) Do. . .	Do. . .	P. L. .	640	20th November 1918.	1 year.
Do. .	(180) Do. . .	Do. . .	P. L .	614·4	Do. .	Do.
Myingyan .	(181) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. . (renewal.)	2,813·4	14th January 1918.	2 years.
Do. .	(182) Do. . .	Do. . .	P. L. .	1,760	21st May 1918	1 year.
Do. .	(183) Maung Net and Maung So Min.	Do. . .	P. L. .	100	21st September 1918.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Myingyan .	(184) Maung Tun Hman and three others.	Mineral oil . .	P. L. .	270	29th August 1918.	1 year.
Do.	(185) Do. . .	Do. . .	P. L. (renewal.)	270	12th December 1917.	2 years.
Myitkyina .	(186) Mr. H. F. Leslie .	Gold and platinum	P. L. .	1,132·8	1st August 1918.	1 year.
Northern Shan States.	(187) Messrs. The Burma Mines, Ltd.	Iron ore . .	P. L. (renewal.)	640	12th February 1918.	2 years.
Do. .	(188) Do. . .	Iron . . .	P. L. .	2,560	13th June 1918.	1 year.
	(189) Do. . .	Coal . . .	P. L. .	2,560	15th June 1918.	Do.
Do.	(190) Do. . .	Do. . . .	P. L. .	3,200	Do. .	Do.
Pakokku	(191) Mr. S. S. Halkar .	Mineral oil . .	P. L. .	640	15th February 1918.	Do.
Do.	(192) Messrs. The Burma Oil Co., Ltd.	Do. . .	M. L. .	640 Block D2 in the Yenangyat oilfield.	9th April 1918	30 years.
Do. .	(193) Mr. J. C. Galstaun	All minerals (except oil).	P. L. .	3,840	29th July 1918.	1 year.
Do. .	(194) Messrs. The Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. (renewal.)	800	6th September 1918.	2 years.
Pegu .	(195) Yeo Sein Guan .	All minerals (except oil).	P. L. .	2,534·40	30th September 1918.	1 year.
Prome .	(196) Maung Myat Thin and Maung Po Tok.	Mineral oil . .	P. L. .	320	28th October 1918.	Do.
Ruby Mines	(197) Maung Po Ye .	Mica . . .	P. L. .	2,560	3rd May 1918	Do.
Do. .	(198) Maung Po Ta .	Do. . . .	P. L. .	2,560	Do. .	Do.
Do. .	(199) Ma Shwe Bin .	Copper . .	P. L. (renewal.)	640	6th May 1918	Do.
Do. .	(200) Mr. S. S. Halkar .	Mica . . .	P. L. .	41	21st June 1918.	Do.
Salween .	(201) Messrs. Steel Bros. & Co., Ltd.	All minerals (except oil).	P. L. .	3,840	26th October 1917.	Do.
Shwebo .	(202) Mr. A. D'Ortez .	All minerals (except oil).	P. L. .	1,068·8	8th April 1918	Do.
Do. .	(203) Messrs. The Burma Oil Co., Ltd.	Mineral oil . .	P. L. (renewal.)	7,040	22nd May 1917.	2 years.
Do. .	(204) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal.)	3,424	23rd February 1918.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Shwebo .	(205) Messrs. The Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. .	1,280	29th November 1918.	1 year.
Southern Shan States.	(206) Maung Thin .	Wolfram . .	P. L. .	3,520	24th October 1917.	Do.
Do. .	(207) Ma Chit Su . .	All minerals (except oil).	P. L. .	640	9th October 1917.	Do.
Do. .	(208) Ma Thein Kyi .	Do. . .	P. L. .	1,280	5th January 1918.	Do.
Do. .	(209) Messrs. Bulloch Bros. & Co., Ltd.	Do. . .	P. L. .	640	25th February 1918.	Do.
Do. .	(210) Mr. Shain Thwe .	Do. . .	P. L. .	1,200	15th April 1918.	Do.
Do. .	(211) Abdul Bari Chowdry.	Do. . .	P. L. .	640	30th April 1918.	Do.
Do. .	(212) Maung Haya .	Do. . .	P. L. .	228·73	23rd April 1918.	Do.
Do. .	(213) Maung Pan Aung .	Do. . .	P. L. .	320	14th June 1918.	Do.
Do. .	(214) Maung Ye . .	Do. . .	P. L. .	191·4	26th June 1918.	Do.
Do. .	(215) Do. . .	Do. . .	P. L. . (renewal.)	140	17th April 1918.	2 years.
Do. .	(216) Mr. E. Taylor .	Wolfram . .	P. L. .	1,715	3rd July 1918	1 year.
Do. .	(217) Messrs. The Bombay-Burma Trading Corporation, Ltd.	All minerals (except oil).	P. L. .	3,828	8th July 1918	Do.
Do. .	(218) Ma Chit Su . .	Do. . .	P. L. .	256	26th August 1918.	Do.
Do. .	(219) Mr. J. Jarvis .	Do. . .	P. L. .	Two areas measuring 832 and 1,832 acres.	19th August 1918.	Do.
Do. .	(220) Messrs. J. A. Begbie & Co.	Coal . .	P. L. .	1,280	4th September 1918.	Do
Do. .	(221) Taw Chin Lye .	Do. . .	P. L. .	739	25th September 1918.	Do.
Do. .	(222) Maung San Hein .	All minerals (except oil).	P. L. .	160	5th December 1918.	Do.
Do. .	(223) Maung Shwe Yin .	Do. . .	P. L. .	80	13th December 1918.	Do.
Do. .	(224) Maung Myaing .	Antimony . .	P. L. .	160	15th October 1918.	Do.
Do. .	(225) Messrs. Steel Bros. & Co., Ltd.	All minerals (except oil).	P. L. . (renewal.)	3,680	17th September 1918.	2 years.
Do. .	(226) Do. . .	Do. . .	P. L. . (renewal.)	2,560	4th September 1918.	Do.

P. L.—*Prospecting License.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(227) Messrs. The Bombay-Burma Trading Corporation, Ltd.	All minerals (except oil).	P. L. .	860	19th March 1918.	1 year.
Do. .	(228) Ma Nyein . .	Do. . .	P. L. .	640	7th February 1918.	Do.
Do. .	(229) Messrs. Booth and Milne.	Do. . .	P. L. .	320	1st February 1918.	Do.
Do. .	(230) Maung Po Hnan .	Do. . .	P. L. .	589	15th February 1918.	Do.
Do. .	(231) Quah Cheng Gwan	Do. .	P. L. .	190	1st March 1918	Do.
Do. .	(232) Messrs. Osman Musti Khan & Co.	Do. . .	P. L. .	551	26th February 1918.	Do.
Do. .	(233) Mr. A. R. H. Ady .	Do. . .	P. L. .	261	25th February 1918.	Do.
Do. .	(234) Maung Shwe Gaing	Do. . .	P. L. .	547	15th March 1918.	Do.
Do. .	(235) C. Swee Pwah .	Do. . .	P. L. .	486	25th March 1918.	Do.
Do. .	(236) Mahomed Aslam Khan.	Do. . .	P. L. (renewal.)	921	4th January 1917.	Do.
Do. .	(237) Ma Sein Daing .	Do. . .	P. L. (renewal.)	574	28th September 1917.	6 months.
Do. .	(238) Messrs. The Bombay-Burma Trading Corporation, Ltd.	Do. . .	P. L. (renewal.)	708	10th October 1917.	1 year.
Do. .	(239) Maung Maung .	Do. . .	P. L. (renewal.)	343	7th October 1917.	Do.
Do. .	(240) Messrs. Foucar & Co., Ltd.	Do. . .	P. L. (renewal.)	112	17th November 1917.	6 months.
Do. .	(241) Maung Paw Tun .	Do. . .	P. L. (renewal.)	450	19th October 1917.	Do.
Do. .	(242) Do. . .	Do. . .	P. L. (renewal.)	947	Do.	Do.
Do. .	(243) Osman Musti Khan	Do. . .	P. L. (renewal.)	2,278	12th October 1917.	Do.
Do. .	(244) Maung E Zin .	Do. . .	P. L. (renewal.)	435	15th November 1917.	3 months.
Do. .	(245) Messrs. R. S. Giles, H. Hamadanee and R. Ady.	Do. . .	P. L. (renewal.)	765	6th December 1917.	6 months.
Do. .	(246) Maung Sein Khaing	Do. . .	P. L. (renewal.)	682	23rd November 1917.	1 year.
Do. .	(247) Maung Ba Don .	Do. . .	P. L. (renewal.)	282	11th November 1917.	Do.
Do. .	(248) Messrs. Ba Thaung Bros. & Co.	Do. . .	P. L. (renewal.)	968	22nd November 1917.	6 months.

P. L.=*Prospecting License.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(249) Messrs. The Bombay Tavoy Mining Co.	All minerals (except oil).	P. L. (renewal.)	780	9th December 1917.	6 months.
Do. .	(250) Maung Lu Chaw, Maung Kya Pe and Ma Khin.	Do. . .	P. L. (renewal.)	358	Do. .	1 year.
Do. .	(251) Ganpat Rai .	Do. . .	P. L. (renewal.)	384	16th December 1917.	Do.
Do. .	(252) Mr. T. Fowle .	Do. . .	P. L. (renewal.)	320	13th December 1917.	Do.
Do. .	(253) Mr. A. G. Fraser .	Do. . .	P. L. (renewal.).	922	22nd January 1918.	Do.
Do. .	(254) Messrs. Eu Kya Ban and A. G. Fraser.	Do. . .	P. L. (renewal.)	548	29th December 1917.	6 months.
Do. .	(255) Maung Saw Hlaing	Do. . .	P. L. (renewal.)	548	2nd January 1918.	1 year.
Do. .	(256) Quah Cheng Gwan	Do. . .	P. L. (renewal.)	640	9th January 1918.	Do.
Do. .	(257) Naitram Rambux	Do. . .	P. L. (renewal.)	240	4th January 1918.	6 months.
Do. .	(258) Mahomed Aslam Khan.	Do. . .	P. L. (renewal.)	921	Do. .	1 year.
Do. .	(259) Maung Sein Khaing	Do. . .	P. L. (renewal.)	640	8th January 1918.	Do.
Do. .	(260) Maung Ni . .	Do. . .	P. L. (renewal.)	640	17th September 1917.	6 months.
Do. .	(261) Messrs. The Bombay-Burma Trading Corporation, Ltd.	Do. . .	P. L. (renewal.)	947	18th November 1917.	1 year.
Do. .	(262) Do. . .	Do. . .	P. L. (renewal.)	1,459	Do. .	Do.
Do. .	(263) Maung Kya Tun .	Do. . .	P. L. (renewal.)	307	20th November 1917.	6 months.
Do. .	(264) Maung E Zin .	Do. . .	P. L. (renewal.)	435	15th February 1918.	1 year.
Do. .	(265) Messrs. The Rangoon Wolfram Co., Ltd.	Do. . .	P. L. .	1,280	9th May 1918	6 months.
Do. .	(266) Do. . .	Do. . .	P. L. .	1,040	Do. .	Do.
Do. .	(267) Mr. G. N. Marks .	Do. . .	P. L. .	799	18th April 1918.	1 years.
Do. .	(268) Messrs. The Tavoy Wolfram Co., Ltd.	Do. . .	P. L. .	543	26th April 1918.	Do.
Do. .	(269) Messrs. Booth and Milne.	Do. . .	P. L. .	13	13th June 1918.	Do.
Do. .	(270) Maung Ngwe Thi .	Do. . .	P. L. .	548	14th June 1918.	6 months.

P. L.=*Prospecting License.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(271) Messrs. Osman Musti Khan & Co.	All minerals (except oil).	P. L. .	297	30th April 1918.	1 year.
Do. .	(272) Messrs. The Rangoon Wolfram Co., Ltd.	Do. . .	P. L. .	1,725	9th May 1918	Do.
Do. .	(273) Mr. A. B. Brown .	Do. . .	P. L. .	625	3rd April 1918.	Do.
Do. .	(274) Maung Ba Don .	Do. . .	P. L. .	84	22nd April 1918.	Do.
Do. .	(275) Mr. A. R. H. Ady	Do. . .	P. L. .	287	20th May 1918.	Do.
Do. .	(276) Maung Me . .	Do. . .	P. L. .	297	25th April 1918.	Do.
Do. .	(277) Mr. F. G. Fitzherbert.	Do. . .	P. L. .	389	20th May 1918.	Do.
Do. .	(278) A. E. O. Mahomed Yusuf.	Do. . .	P. L. .	487	9th April 1918.	Do.
Do. .	(279) Mr. Ganpat Rai Kutwal.	Do. .	P. L. .	333	13th May 1918.	Do.
Do. .	(280) Mr. A. E. O. Mahomed Yusuf.	Do. . .	P. L. .	415	16th May 1918.	Do.
Do. .	(281) Lim Eng Cheong .	Do. . .	P. L. .	888	20th June 1918.	Do.
Do. .	(282) Maung Lu Pe .	Do. . .	P. L. .	737	18th June 1918.	Do.
Do. .	(283) Ma Mo Thu . .	Do. . .	P. L. . (renewal.)	617	14th December 1917.	6 months.
Do. .	(284) Ma Kin . .	Do. . .	P. L. . (renewal.)	719	19th December 1917.	Do.
Do. .	(285) Messrs. Steel Bros. & Co., Ltd.	Do. . .	P. L. . (renewal.)	620	6th January 1918.	1 year.
Do. .	(286) Maung Me . .	Do. . .	P. L. . (renewal.)	640	29th November 1917.	6 months.
Do. .	(287) Khoo Tun Byan .	Do. . .	P. L. . (renewal.)	148	30th November 1917.	1 year.
Do. .	(288) Messrs. Gillanders, Arbuthnot & Co.	Do. . .	P. L. . (renewal.)	760	25th November 1917.	Do.
Do. .	(289) Maung Mya Pe .	Do. . .	P. L. . (renewal.)	537	26th December 1917.	6 months.
Do. .	(290) Messrs. Steel Bros. & Co., Ltd.	Do. . .	P. L. . (renewal.)	1,422	21st December 1917.	1 year.
Do. .	(291) Mr. G. N. Marks .	Do. . .	P. L. . (renewal.)	720	20th November 1917.	6 months.
Do. .	(292) Messrs. Steel Bros. & Co., Ltd.	Do. . .	P. L. . (renewal.)	716	1st February 1918.	1 year.
Do. .	(293) Messrs. Osman Musti Khan & Co.	Do. . .	P. L. . (renewal.)	747	10th February 1918.	6 months.

P. L.—*Prospecting License.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(294) Maung Sein Thwe	All minerals (except oil).	P. L. (renewal.)	589	19th February 1918.	1 year.
Do. .	(295) Mr. G. N. Marks .	Do. . .	P. L. (renewal.)	768	27th October 1917.	Do.
Do. .	(296) Do. . .	Do. . .	P. L. (renewal.)	476	26th February 1918.	Do.
Do. .	(297) Mr. B. B. Kaka .	Do. . .	P. L. (renewal.)	589	28th November 1917.	Do.
Do. .	(298) Maung Shwe Gaing	Do. . .	P. L. (renewal.)	512	23rd March 1918.	6 months.
Do. .	(299) Khoo Tun Byan .	Do. . .	P. L. (renewal.)	322	21st March 1918.	1 year.
Do. .	(300) Mahomed Aslam Khan.	Do. . .	P. L. (renewal.)	392	24th March 1918.	Do.
Do.	(301) Ma Mya Yin .	Do. . .	P. L. (renewal.)	1,075	26th March 1918.	6 months.
Do.	(302) Maung Ni . .	Do. . .	P. L. (renewal)	640	17th March 1918.	Do.
Do.	(303) Maung Sein Thwe	Do. . .	P. L. (renewal.)	256	9th April 1918.	Do.
Do. .	(304) C. Soo Don . .	Do. . .	P. L. (renewal.)	604	23rd April 1918.	1 year.
Do. .	(305) Ung Kyi Pe .	Do. . .	P. L. (renewal.)	614	17th May 1918.	Do.
Do. .	(306) Mr. G. N. Marks .	Do. . .	P. L. (renewal.)	238	24th February 1918.	Do.
Do. .	(307) Messrs. Bulloch Bros. & Co., Ltd.	Do. . .	P. L. .	1,101	1st August 1918.	6 months.
Do. .	(308) Ma Thaw . .	Do. . .	P. L. .	313	13th June 1918.	Do.
Do. .	(309) Messrs. Foucar & Co., Ltd.	Do. . .	P. L. .	1,582	27th August 1918.	1 year.
Do. .	(310) Mr. R. C. N. Twite	Do. . .	P. L. .	609	16th August 1918.	Do.
Do. .	(311) C. Swee Pwah .	Do. . .	P. L. .	159	21st August 1918.	Do.
Do. .	(312) Messrs. Foucar & Co., Ltd.	Do. . .	P. L. .	460	1st July 1918	Do.
Do. .	(313) Messrs. The Rangoon Wolfram Co., Ltd.	Do. . .	P. L. .	1,638	6th September 1918.	Do.
Do. .	(314) Mr. S. Boon The .	Do. . .	P. L. .	814	22nd August 1918.	Do.
Do. .	(315) Messrs. Foucar & Co., Ltd.	Do. . .	P. L. .	476	27th August 1918.	Do.

P. L.=*Prospecting License.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(316) Maung Ba Don .	All minerals (except oil).	P. L. .	814	26th August 1918.	1 year.
Do. .	(317) Quah Cheng Tock	Do. . .	P. L. .	443	Do. .	Do.
Do. .	(318) Maung Po Gaung .	Do. . .	P. L. .	460	14th August 1918.	Do.
Do. .	(319) Maung Kya Tun .	Do. . .	P. L. .	604	16th August 1918.	6 months.
Do. .	(320) Maung Po Swe .	Do. . .	P. L. .	876	5th September 1918.	1 year.
Do. .	(321) Maung Ze Ya .	Do. . .	P. L. .	15	28th August 1918.	Do.
Do. .	(322) A. S. Mahomed .	Do. . .	P. L. (renewal.)	358	5th August 1917.	Do.
Do. .	(323) Messrs. The High Speed Steel Alloys Mining Co., Ltd.	Do. . .	P. L. (renewal.)	1,163	11th August 1917.	Do.
Do. .	(324) Do. . .	Do. . .	P. L. (renewal.)	1,818	11th September 1917.	Do.
Do. .	(325) Chan Kin Way .	Do. . .	P. L. (renewal.)	411	26th January 1918.	6 months.
Do. .	(326) C. Soo Don . .	Do. . .	P. L. (renewal.)	488	22nd July 1918.	1 year.
Do. .	(327) Messrs. The Rangoon Wolfram Co., Ltd.	Do. . .	P. L. (renewal.)	445	7th January 1918.	6 months.
Do. .	(328) Messrs. Sein Daing Bros.	Do. . .	P. L. (renewal.)	717	23rd February 1918.	1 year.
Do. .	(329) Do. . .	Do. . .	P. L. (renewal.)	726	Do. .	Do.
Do. .	(330) Messrs. Booth and Milne.	Do. . .	P. L. (renewal.)	5	14th February 1918.	Do.
Do. .	(331) Ma Sein Dine .	Do. . .	P. L. (renewal.)	574	28th March 1918.	6 months.
Do. .	(332) Maung Po Hnan .	Do. . .	P. L. (renewal.)	640	26th March 1918.	1 year.
Do. .	(333) Mr. A. D. Brown .	Do. . .	P. L. (renewal.)	666	5th April 1918.	Do.
Do. .	(334) Messrs. Steel Bros. & Co., Ltd.	Do. . .	P. L. (renewal.)	589	16th May 1918.	Do.
Do. .	(335) Do. . .	Do. . .	P. L. (renewal.)	1,600	13th March 1918.	Do.
Do. .	(336) Messrs. The Bombay Tavoy Mining Co.	Do. . .	P. L. (renewal.)	780	9th June 1918.	6 months.
Do. .	(337) Maung Saw Hlaing	Do. . .	P. L. (renewal.)	179	17th May 1918.	1 year.

P. L.=*Prospecting License.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(338) Messrs. Foucar & Co., Ltd.	All minerals (except oil).	P. L. . (renewal.)	112	17th May 1918.	6 months.
Do. .	(339) Maung Po U .	Do. . .	P. L. . (renewal.)	1,020	24th March 1918.	1 year.
Do. .	(340) Khoo Zun Nee .	Do. . .	P. L. . (renewal.)	739	7th June 1918.	6 months.
Do. .	(341) Messrs. Steel Bros. & Co., Ltd.	Do. . .	P. L. . (renewal.)	184	11th June 1918.	1 year.
Do. .	(342) Mr. A. R. H. Ady .	Do. . .	P. L. . (renewal.)	512	28th May 1918.	6 months.
Do. .	(343) Ong Hoe Kyin .	Do. . .	P. L. . (renewal.)	179	13th June 1918.	Do.
Do. .	(344) Neitram Rambux	Do. . .	P. L. . (renewal.)	240	4th July 1918	Do.
Do. .	(345) Maung Me . .	Do. . .	P. L. . (renewal.)	640	29th May 1918.	1 year.
Do. .	(346) Messrs. Steel Bros. & Co., Ltd.	Do. . .	P. L. . (renewal.)	320	20th June 1918.	Do.
Do. .	(347) Maung Mya Pe .	Do. . .	P. L. . (renewal.)	469	26th June 1918.	6 months.
Do. .	(348) Messrs. Steel Bros. & Co., Ltd.	Do. . .	P. L. . (renewal.)	588	28th June 1918.	1 year.
Do. .	(349) Mahomed Aslam Khan.	Do. . .	P. L. . (renewal.)	921	4th January 1918.	Do.
Do. .	(350) Messrs. The High Speed Steel Alloys Mining Co., Ltd.	Do. . .	P. L. . (renewal.)	51	27th June 1918.	Do.
Do. .	(351) Messrs. The Rangoon Wolfram Co., Ltd.	Do. . .	P. L. . (renewal.)	445	7th July 1918	Do.
Do. .	(352) C. Gyaw Saing .	Do. . .	P. L. . (renewal.)	1,106	22nd August 1918.	Do.
Do. .	(353) Messrs. The Rangoon Wolfram Co., Ltd.	Do. . .	M. L.	305·92	24th February 1917.	30 years.
Do. .	(354) Mr. F. G. Fitzherbert.	Do. . .	P. L. .	835	4th October 1918.	6 months.
Do. .	(355) Do. . .	Do. . .	P. L. .	164	3rd December 1918.	1 year.
Do. .	(356) Maung Tun . .	Do. . .	P. L. .	507	18th November 1918.	6 months.
Do. .	(357) Messrs. Osman Musti Khan & Co.	Do. . .	P. L. .	287	23rd December 1918.	1 year.
Do. .	(358) Maung Po Myee .	Do. . .	P. L. .	179	25th November 1918.	6 months.
Do. .	(359) Maung Kya Tun .	Do. . .	P. L. .	282	20th December 1918.	Do.
Do. .	(360) Mr. S. Crawshaw .	Do. . .	P. L. . (renewal.)	328	1st June 1918	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(361) Maung Paw Tun .	All minerals (except oil).	P. L. (renewal.)	947	10th April 1918.	1 year.
Do. .	(362) Mr. A. R. H. Ady	Do. . .	P. L. (renewal.)	1,090	28th June 1918.	Do.
Do. .	(363) Maung Than and Ma Thein.	Do. . .	P. L. (renewal.)	589	29th June 1918.	Do.
Do. .	(364) Mr. G. N. Marks .	Do. . .	P. L. (renewal.)	620	20th May 1918.	Do.
Do. .	(365) Chan Kin Way .	Do. . .	P. L. (renewal.)	182	8th July 1918	Do.
Do. .	(366) Mr. A. S. Mahomed	Do. . .	P. L. (renewal.)	358	5th August 1918.	Do.
Do. .	(367) Do. . .	Do. . .	P. L. (renewal.)	1,894	12th June 1918.	Do.
Do. .	(368) Chan Kin Way .	Do. . .	P. L. (renewal.)	411	26th July 1918.	6 months.
Do. .	(369) Mr. G. Willison .	Do. . .	P. L. (renewal.)	317	26th November 1918.	1 year.
Do. .	(370) The Hon'ble Mr. Lim Chin Tsong.	Do. . .	P. L. (renewal.)	320	12th October 1918.	Do.
Do. .	(371) Maung Sein Thwe	Do. . .	P. L. (renewal.)	256	9th October 1918.	6 months.
Do. .	(372) Messrs. The Rangoon Wolfram Co., Ltd.	Do. . .	P. L. (renewal.)	1,280	9th November 1918.	Do.
Do. .	(373) Messrs. Osman Musti Khan & Co.	Do. . .	P. L. (renewal.)	747	10th August 1918.	6 months.
Thaton .	(374) Aung Ba Wet .	Do. . .	P. L. .	204·8	7th March 1918.	1 year.
Do. .	(375) Maung Kaing .	Do. . .	P. L. .	1,094·4	29th January 1918.	Do.
Do. .	(376) Yeo Sein Gwan .	Do. . .	P. L. .	377·6	8th February 1918.	Do.
Do. .	(377) Lim Kar Chang .	Do. . .	P. L. .	1,747·2	9th February 1918.	Do.
Do. .	(378) Tan Kin Chye and Aung Ba Wet.	Do. . .	P. L. .	576	13th February 1918.	Do.
Do. .	(379) Maung Kaing .	Do. . .	P. L. .	153·6	7th February 1918.	Do.
Do. .	(380) Ma Thein Zin .	Do. . .	P. L. (renewal.)	281·6	1st February 1918.	Do.
Do. .	(381) Ma Thet Hta .	Do. . .	P. L. (renewal.)	608	2nd January 1918.	6 months.
Do. .	(382) Li Ah Lye . .	Do. . .	P. L. (renewal.)	640	17th December 1917.	1 year.

P. L.=*Prospecting License.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thaton	(383) Mr. H. E. Singleton	All mineral (except oil).	P. L. (renewal.)	1,657·6	20th February 1918.	1 year.
Do.	(384) Maung Khaing	Do.	P. L. (renewal.)	678·4	13th February 1918.	Do.
Do.	(385) The Hon'ble Mr. Lim Chin Tsong.	Do.	P. L. (renewal.)	1,376	28th November 1917.	Do.
Do.	(386) Maung Pan Dwe	Do.	P. L. (renewal.)	979·2	10th February 1918.	Do.
Do.	(387) The Hon'ble Mr. U Po Tha.	Do.	P. L.	371·2	31st May 1918.	Do.
Do.	(388) Mr. J. A. Mack	Wolfram	P. L.	2,073·6	12th March 1918.	Do.
Do.	(389) Mr. E. J. Holberton	All minerals (except oil).	P. L.	1,100·8	1st May 1918	Do.
Do.	(390) See Kyu Lye	Do.	P. L.	486·4	5th June 1918	Do.
Do.	(391) Mr. H. H. A. Peters	Do.	P. L.	640	6th June 1918	Do.
Do.	(392) Mr. J. A. Angus	Do.	P. L.	409·6	Do.	Do.
Do.	(393) Maung Chit Maung	Do.	P. L. (renewal.)	1,836·8	11th April 1918.	Do.
Do.	(394) L. Heng Seng	Do.	P. L. (renewal.)	678·1	12th March 1918.	Do.
Do.	(395) Messrs. A. V. Joseph & Co.	Do.	P. L. (renewal.)	524·8	25th May 1918.	Do.
Do.	(396) P. M. Pillay	Do.	P. L. (renewal.)	1,491·2	11th April 1918.	Do.
Do.	(397) Maung Tun Hla	Do.	P. L. (renewal.)	1,952	24th May 1918.	Do.
Do.	(398) Messrs. F. A. Boog and H. Hamadanee.	Do.	P. L.	204·8	20th August 1918.	Do.
Do.	(399) M. Ah Khee	Do.	P. L.	2,713·6	7th July 1918	Do.
Do.	(400) Lim Kar Chang	Do.	P. L.	409·60	15th July 1918.	Do.
Do.	(401) Maung Shwe Goh	Do.	P. L. (renewal.)	1,049·6	6th June 1918	Do.
Do.	(402) Ma Thet Hta	Do.	P. L. (renewal.)	608	2nd July 1918	6 months.
Do.	(403) P. Murugasen Pillay.	Do.	P. L. (renewal.)	29·44	20th June 1918.	Do.
Do.	(404) Messrs. F. A. Boog and C. P. Vlleland.	Do.	P. L. (renewal.)	819·20	14th July 1918.	1 year.
Do.	(405) U. Shan Byu	Do.	P. L. (renewal.)	2,144	23rd July 1918.	Do.
Do.	(406) Lim Kar Chang	Do.	P. L. (renewal.)	876·8	3rd May 1918	Do.

P. L. = *Prospecting License.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thaton .	(407) Mr. C. R. Connell .	All minerals (except oil).	P. L. (renewal.)	1,881·60	29th May, 1918.	1 year.
Do. .	(408) The Hon'ble Mr. Lim Chin Tsong.	Do. . .	P. L. .	5,478·4	4th December 1918.	Do.
Do. .	(409) Abdul Karim Jeewa.	Do. . .	P. L. .	4,902·4	8th November 1918.	Do.
Do. .	(410) Maung Gyi . .	Do. . .	P. L. .	7,027·2	22nd November 1918.	Do.
Do. .	(411) Messrs. Hussein Bros.	Do. . .	P. L. .	1,920	3rd December 1918.	Do.
Do. .	(412) Maung Hte . .	Do. . .	P. L. .	614·40	8th December 1918.	Do.
Do. .	(413) The Hon'ble Mr. Lim Chin Tsong.	Do. . .	P. L. (renewal.)	396·8	11th April 1918.	Do.
Do. .	(414) Ma Thet Hta .	Do. . .	P. L. (renewal.)	608	1st January 1919.	Do.
Thayetmyo	(415) Messrs. The London-Rangoon Trading Co., Ltd.	Mineral oil . .	P. L. .	9,574·4	14th December 1917.	Do.
Do. .	(416) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal.)	2,858·9 (Blocks Nos. 3 and 4 excluding the area held by the British-Burma Petroleum Co., Ltd., in Block No. 4), Blocks Nos. 16 and 17, western half of Block No. 18 and eastern half of Block No. 19 of the Minhla Oilfield.	21st December 1917.	2 years.
Do. .	(417) Mr. S. S. Halkar .	Do. . .	P. L. .	640	22nd March 1918.	1 year.
Do. .	(418) Messrs. The London-Rangoon Trading Co., Ltd.	Do. . .	P. L. .	2,880	10th April 1918.	Do.
Do.	(419) Messrs. The Twinzas Oil Co., Ltd.	Do. . .	P. L. .	1,920 (Blocks Nos. 13, 20 and 23 of the Minhla Oilfield.)	4th June 1918	Do.
Do. .	(420) Mr. B. Cowasji .	Do. . .	P. L. .	1,123·2 (Blocks Nos. 1, 2 and 8 and the eastern half of Block No. 9 of the Minhla Oilfield.)	4th June 1918	Do.

P. L. = *Prospecting License.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thayetmyo.	(421) Maung Kyaw .	Coal . . .	P. L. .	1,280	17th July 1918.	1 year.
Do. .	(422) Messrs. The London-Rangoon Trading Co., Ltd.	Mineral oil . .	P. L. .	2,560 (Blocks Nos. 26 and 27, the western halves of Blocks Nos. 9, 25 and 28 and the eastern half of Block No. 30 of the Minhla Oilfield.)	13th July 1918.	Do.
Do. .	(423) Maung San Hein .	Coal . . .	P. L. .	640	22nd August 1918.	Do.
Do. .	(424) Messrs. The London-Rangoon Trading Co., Ltd.	Mineral oil . .	P. L. . (renewal.)	10,240	30th May 1918.	2 years.
Do. .	(425) Mr. C. M. Surty .	Do. . .	P. L. .	1,095·68	2nd October 1918.	1 year.
Do. .	(426) Maung San Hein .	Coal . . .	P. L. .	640	29th October 1918.	Do.
Do. .	(427) Messrs. The London-Rangoon Trading Co., Ltd.	Mineral oil . .	P. L. .	1,280	10th August 1918.	Do.
Upper Chindwin.	(428) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. .	12,800	12th September 1917.	Do.
Do. .	(429) Do. . .	Do. . .	P. L. . (renewal.)	3,200	24th May 1918.	2 years.
Yamethin .	(430) C. Soon Thin .	Wolfram . .	P. L. .	320	18th June 1918.	1 year.
Do. .	(431) Maung Po Ngwe .	Do. . .	P. L. .	524·8	22nd May 1918.	Do.
Do. .	(432) Messrs. Bechardass Manekchand Kharwar.	Do. . .	P. L. .	1,369·6	20th May 1918.	Do.
Do. .	(433) Maung Kyi . .	Do. . .	P. L. .	582·4	18th May 1918.	Do.
Do. .	(434) Mr. P. L. Peters .	All minerals (except oil).	P. L. .	473·6	15th May 1918.	Do.
Do. .	(435) The Hon'ble Mr. Lim Chin Tsong.	Do. . .	P. L. .	819·2	11th June 1918.	Do.
Do. .	(436) Maung Tin . .	Tin . . .	P. L. .	3,187·2	18th May 1918.	Do.
Do. .	(437) Maung Po Sein .	Wolfram . .	P. L. .	1,836·8	Do. .	Do.
Do. .	(438) Maung Kyi . .	Lead . .	P. L. .	1,804·8	Do. .	Do.
Do. .	(439) Maung Po Sein .	Do. .	P. L. .	1,676·8	Do. .	Do.

P. L. = *Prospecting License.*

BURMA—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Yamethin .	(440) Messrs. Steel Bros. & Co., Ltd.	All minerals (except oil).	P. L. .	870·4	2nd June 1918	1 year.
Do. .	(441) Maung Ba Nyun .	Do. . .	P. L. .	1,356·8	18th June 1918.	Do.
Do. .	(442) Maung Po Ngwe .	Do. . .	P. L. .	1,920	18th May 1918.	Do.
Do. .	(443) Maung Aung Hmoon.	Lead . .	P. L. .	2,560	19th June 1918.	Do.
Do. .	(444) Maung Min Din .	Wolfram . .	P. L. .	512	1st June 1918	Do.
Do. .	(445) Maung Kyi . .	All minerals (except oil).	P. L. .	1,318·4	14th September 1918.	Do.
Do. .	(446) Li Ah Lye . .	Do. . .	P. L. .	1,600	21st August 1918.	Do.
Do. .	(447) Maung Po Ngwe .	Do. . .	P. L. .	729·6	1st July 1918	Do.
Do. .	(448) Mr. Shein Thwe .	Do. . .	P. L. .	1,248	13th September 1918.	Do.
Do. .	(449) Mr. John Jarvis .	Do. . .	P. L. .	1,958·4	9th August 1918.	Do.
Do. .	(450) Messrs. The Rangoon Wolfram Co., Ltd.	Do. . .	P. L. .	1,670·4	3rd September 1918.	Do.
Do. .	(451) Do. . .	Do. . .	P. L. .	1,920	Do. .	Do.
Do. .	(452) Messrs. Hussein Bros.	Do. . .	P. L. .	2,624	6th September 1918.	Do.
Do. .	(453) Mr. M. J. Ispahany	Do. . .	P. L. .	2,176	9th August 1918.	Do.
Do. .	(454) Maung Po Hlwa .	Do. . .	P. L. .	1,177·6	26th September 1918.	Do.
Do. .	(455) Mr. M. P. A. Maricar.	Do. . .	P. L. .	1,920	Do. .	Do.
Do. .	(456) Mr. W. H. Heard White.	Do. . .	P. L. .	640	13th December 1918.	Do.
Do. .	(457) Maung Kyi .	Do. . .	P. L. .	1,440	6th November 1918.	Do.
Do. .	(458) Maung Ba Nyun .	Do. . .	P. L. .	2,963·2	4th October 1918.	Do.
Do. .	(459) Messrs. The Rangoon Wolfram Co., Ltd.	Do. . .	P. L. .	1,676·8	14th November 1918.	Do.
Do. .	(460) Messrs. Hussein Bros.	Do. . .	P. L. .	2,150·4	22nd November 1918.	Do.
Do. .	(461) Maung Po Hlwa .	Do. . .	P. L. .	524·8	2nd November 1918.	Do.
Do. .	(462) Mr. M. Hashim .	Do. . .	P. L. .	1,024	21st November 1918.	Do.
Do. .	(463) Mr. Yeo Poon Hwat	Do. . .	P. L. .	1,369·6	19th December 1918.	Do.

P. L.=*Prospecting License.*

CENTRAL PROVINCES.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(464) Pandit Rewashankar.	Manganese .	P. L. .	105	26th March 1918.	1 year.
Do. .	(465) Rai Bahadur Bisesardas Daga & Bros.	Do. . .	M. L. .	240	19th December 1917.	30 years.
Do. .	(466) Central India Mining Co., Ltd.	Do. . .	M. L. .	19	19th January 1918.	10 years.
Do. .	(467) Mr. C. S. Harris .	Bauxite . .	P. L. .	125	1st February 1918.	1 year.
Do. .	(468) Babu Kripashankar	Manganese . .	M. L. .	96	19th December 1917.	15 years.
Do. .	(469) Pandit Rewashankar.	Do. . .	M. L. .	48	22nd December 1917.	5 years.
Do. .	(470) Do. . .	Do. . .	M. L. .	51	11th January 1918.	Do.
Do. .	(471) Seth Shriram .	Do. . .	P. L. .	90	1st February 1918.	1 year.
Do. .	(472) Do. . .	Do. . .	P. L. .	298	16th February 1918.	Do.
Do. .	(473) Mr. C. S. Harris .	Bauxite . .	P. L. .	469	1st February 1918.	Do.
Do. .	(474) Messrs. Tata Sons & Co.	Do. . .	P. L. .	65	Do. .	Do.
Do. .	(475) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	3,398	4th March 1918.	Do.
Do. .	(476) Seth Goverdhandas	Manganese . .	P. L. .	62	1st February 1918.	Do.
Do. .	(477) Messrs. Tata Sons & Co.	Bauxite . .	P. L. .	533	Do. .	Do.
Do. .	(478) Do. . .	Do. . .	P. L. .	44	Do. .	Do.
Do. .	(479) Do. . .	Do. . .	P. L. .	151	Do. .	Do.
Do. .	(480) Do. . .	Do. . .	P. L. .	412	Do. .	Do.
Do. .	(481) Do. . .	Do. . .	P. L. .	32	Do. .	Do.
Do. .	(482) Do. . .	Do. . .	P. L. .	580	Do. .	Do.
Do. .	(483) Do. . .	Do. . .	P. L. .	628	Do. .	Do.
Do. .	(484) Do. . .	Do. . .	P. L. .	525	Do. .	Do.
Do. .	(485) Do. . .	Do. . .	P. L. .	402	Do. .	Do.
Do. .	(486) Do. . .	Do. . .	P. L. .	267	Do. .	Do.
Do. .	(487) Do. . .	Do. . .	P. L. .	397	Do. .	Do.
Do. .	(488) Do. . .	Do. . .	P. L. .	56	Do. .	Do.
Do. .	(489) Do. . .	Do. . .	P. L. .	253	Do. .	Do.
Do. .	(490) Do. . .	Do. . .	P. L. .	20	Do. .	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(491) Seth Shriram .	Manganese . .	P. L. .	66	16th February 1918.	1 year.
Do. .	(492) Messrs. Tata Sons & Co.	Bauxite . .	P. L. .	116	1st February 1918.	Do.
Do. .	(493) Do. . .	Do. . .	P. L. .	93	Do. .	Do.
Do. .	(494) Do. . .	Do. . .	P. L. .	91	Do. .	Do.
Do. .	(495) Do. . .	Do. . .	P. L. .	64	Do. .	Do.
Do. .	(496) Pandit Kripashankar.	Manganese . .	P. L. .	22	7th May 1918	Do.
Do. .	(497) Do. . .	Do. . .	M. L. .	26	29th April 1918.	15 years.
Do. .	(498) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	52	27th May 1918.	1 year.
Do. .	(499) Messrs. Tata Sons & Co.	Do. . .	M. L. .	600	16th April 1918.	5 years.
Do. .	(500) Do. . .	Bauxite . .	P. L. .	49	7th May 1918	1 year.
Do. .	(501) Do. . .	Do. . .	P L. .	16	Do. .	Do.
Do. .	(502) Do. . .	Do. . .	P. L. .	781	5th May 1918	Do.
Do. .	(503) Pandit Rewashankar.	Manganese . .	M. L. .	18	22nd December 1917.	5 years.
Do. .	(504) Messrs. Tata Sons & Co.	Bauxite . .	P. L. .	28	28th June 1918.	1 year.
Do. .	(505) Mir Aslam Khan .	Manganese . .	P. L. .	140	30th April 1918.	Do.
Do. .	(506) Indian Manganese Co., Ltd.	Do. . .	P. L. .	50	19th May 1918.	Do.
Do. .	(507) Do. . .	Do. . .	P. L. .	7	Do. .	Do.
Do. .	(508) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	59	26th July 1918.	Do.
Do. .	(509) Do. . .	Do. . .	P. L. .	27	Do. .	Do.
Do. .	(510) Do. . .	Do. . .	P. L. .	120	Do. .	Do.
Do. .	(511) Do. . .	Do. . .	P. L. .	29	5th July 1918	Do.
Do. .	(512) Do. . .	Do. . .	P. L. .	131	26th July 1918.	Do.
Do. .	(513) Do. . .	Mica . . .	P. L. .	124	27th August 1918.	Do.
Do. .	(514) Do. . .	Manganese . .	P. L. .	22	2nd July 1918	Do.
Do. .	(515) Do. . .	Do. . .	P. L. .	41	21st September 1918.	Do.
Do. .	(516) Do. . .	Do. . .	P. L. .	182	26th July 1918.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(517) Khan Bahadur Byramji Pestonji.	Manganese . .	P. L. .	552	27th August 1918.	1 year.
Do. .	(518) Do. . .	Do. . .	P. L. (renewal.)	171	13th October 1918.	6 months.
Do. .	(519) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. .	480	6th August 1918.	1 year.
Do. .	(520) Rai Bahadur Bisesardas Daga.	Do. . .	P. L. .	568	26th July 1918.	Do.
Do. .	(521) Seth Shriram .	Do. . .	P. L.	9	9th August 1918.	Do.
Do. .	(522) Do. . .	Do. . .	P. L. .	6	27th August 1918.	Do.
Do. .	(523) Do. . .	Do. . .	P. L. .	61	9th August 1918.	Do.
Do. .	(524) Do. . .	Do. . .	P. L. .	11	Do. .	Do.
Do. .	(525) Do. . .	Do. . .	P. L. .	63	27th August 1918.	Do.
Do. .	(526) Do. . .	Do. . .	P. L. .	12	Do. .	Do.
Do. .	(527) Do . .	Do. . .	P. L. .	6	9th August 1918.	Do.
Do. .	(528) Pandit Rewa Shankar.	Do. . .	P. L. .	22	1st August 1918.	Do.
Do.	(529) Messrs. Bahmansha Foujdar Bros.	Do. . .	P. L. .	131	4th September 1918.	Do.
Do. .	(530) Mr. C. Harris .	Mica . .	P. L. .	46	Do. .	Do.
Do. .	(531) Do. . .	Manganese . .	P. L. .	44	Do. .	Do.
Do. .	(532) Pandit Kripashankar.	Do. . .	P. L. .	19	Do. .	Do.
Do. .	(533) Do. . .	Do. . .	P. L. .	254	Do. .	Do.
Do. .	(534) Indian Manganese Co., Ltd.	Do. . .	P. L. .	84	2nd July 1918	Do.
Do. .	(535) Do. . .	Do. . .	P. L. .	91	Do. .	Do.
Do. .	(536) Mr. M. A. Pasha .	Do. . .	P. L. .	156	4th September 1918.	Do.
Do. .	(537) Messrs. Tata Sons & Co.	Bauxite . .	P. L. .	49	1st August 1918.	Do.
Do. .	(538) Do. . .	Do. . .	P. L. .	69	Do. .	Do.
Do. .	(539) Do. . .	Do. . .	P. L. .	77	Do. .	Do.
Do. .	(540) Do. . .	Do. . .	P. L. .	1,365	27th August 1918.	Do.
Do. .	(541) Do. . .	Do. . .	P. L. .	187	1st August 1918.	Do.

P. L.—*Prospecting License.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(542) Messrs. Tata Sons & Co.	Bauxite . .	P. L. .	469	1st August 1918.	1 year.
Do. .	(543) Seth Jagannath .	Manganese . .	P. L. (renewal.) .	313	13th August 1918.	6 months.
Do. .	(544) Musstt. Govindi Bai.	Do. . .	P. L. (renewal.) .	45	30th September 1918.	Do.
Do. .	(545) Do. . .	Do. . .	P. L. (renewal.) .	348	13th September 1918.	Do.
Do. .	(546) Babu Kripashankar.	Do. . .	P. L. .	578	11th October 1918.	1 year.
Do. .	(547) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	141	Do. .	Do.
Do. .	(548) Do. . .	Do. . .	P. L. .	34	13th December 1918.	Do.
Do. .	(549) Seth Govardhandas	Do. . .	M. L. .	7	22nd November 1918.	3 years.
Do. .	(550) Babu Kripashankar	Do. . .	P. L. .	113	11th October 1918.	1 year.
Do. .	(551) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	174	22nd November 1918.	Do.
Do. .	(552) Rao Sahib D. Lakshminarayan.	Do. . .	P. L. .	365	23rd December 1918.	Do.
Do. .	(553) Messrs. Tata Sons, Ltd.	Bauxite . .	P. L. .	387	13th December 1918.	Do.
Do. .	(554) Do. . .	Do. . .	P. L. .	213	Do. .	Do.
Do. .	(555) Do. . .	Do. . .	P. L. .	522	Do. .	Do.
Betul .	(556) Hon'ble Mr. M. R. Dixit.	Graphite .	P. L. .	2,837	8th January 1918.	Do.
Do. .	(557) Messrs. Bahmansha Fouzdar Bros.	Do. . .	P. L. .	115	23rd April 1918.	Do.
Do. .	(558) Do. . .	Coal and graphite	P. L. .	83	Do. .	Do.
Do. .	(559) Shaikh Shahabuddin.	Coal . . .	P. L. .	514	30th October 1918.	Do.
Bhandara .	(560) Khan Bahadur Byramji Pestonji.	Manganese . .	P. L. .	18	26th February 1918.	Do.
Do. .	(561) Seth Jagannath .	Do. . .	P. L. .	15	26th April 1918.	Do.
Do. .	(562) Khan Bahadur Byramji Pestonji.	Do. . .	M. L. .	21	25th April 1918.	5 years.
Do. .	(563) Seth Shriram .	Corundum . .	P. L. .	40	10th June 1918.	1 year.
Do. .	(564) Do. . . .	Do. . .	P. L. .	16	6th May 1918	Do.
Do. .	(565) Do. . .	Do. . .	P. L. .	101	23rd May 1918.	

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara .	(566) Indian Manganese Co., Ltd.	Manganese . .	P. L. .	608	14th May 1918.	1 year.
Do. .	(567) Seth Govardhandas	Do. . .	M. L. .	27	2nd September 1918.	5 years.
Do. .	(568) Seth Shriram .	Do. . .	P. L. .	27	24th August 1918.	1 year.
Do. .	(569) Messrs. Lal Behari Naraindas and Ramcharan Shankar Lal.	Do. . .	P. L. . (renewal.)	16	11th July 1918.	Do.
Do. .	(570) Seth Govardhandas	Do. . .	P. L. .	27	19th November 1918.	Do.
Do. .	(571) Seth Shriram .	Corundum . .	P. L. .	3	Do. .	Do.
Chanda .	(572) Hon'ble Mr. M. R. Dixit.	Lead . .	P. L. .	3,616	29th April 1918.	Do.
Do. .	(573) Shaikh Shahabudin	Lead and antimony	P. L. .	614	8th February 1918.	Do.
Do. .	(574) Mr. Padamsy Narsibhoy.	Coal . . .	P. L. .	108	15th January 1918.	Do.
Do. .	(575) Do. . .	Do. . .	P. L. .	254	1st July 1918	Do.
Do. .	(576) Messrs. Hashambhoy & Sons.	Galena . .	P. L. .	1,350	26th September 1918.	Do.
Do. .	(577) Mr. Padamsy Narsibhoy.	Coal . . .	P. L. .	162	2nd December 1918.	Do.
Do. .	(578) Do. . .	Do. . . .	P. L. .	165	Do. .	Do.
Do. .	(579) Do. . .	Do. . . .	P. L. .	175	Do. .	Do.
Chhindwara	(580) Messrs. Balbha & Mohanlal.	Manganese . .	P. L. .	401	19th March 1918.	Do.
Do. .	(581) Shaikh Shahabuddin.	Coal . . .	P. L. .	760	11th April 1918.	Do.
Do. .	(582) Seth Lakhmichand	Do. . . .	P. L. .	6	3rd October 1918.	Do.
Do. .	(583) Messrs. Shaw, Wallace & Co.	Do. . . .	P. L. .	495	10th October 1918.	Do.
Do. .	(584) Mir Aslam Khan .	Do. . . .	P. L. .	566	15th November 1918.	Do.
Do. .	(585) Seth Lakhmichand	Do. . . .	P. L. .	185	6th December 1918.	Do.
Jubbulpore	(586) Mr. P. C. Dutt .	Manganese . .	M. L. .	5	4th April 1918	Will expire with the original lease dated the 4th September 1915, to which it is supplementary.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jubbalpore	(587) Khan Bahadur Byramji Pestonji.	Manganese . .	P. L. .	130	6th April 1918	1 year.
Do. .	(588) Messrs. Villiers Colliery Co.	Coal . . .	P. L. .	1,673	15th March 1918.	Do.
Do. .	(589) Mr. P. C. Dutt .	Iron and Felspar	P. L. .	95	9th April 1918	Do.
Do. .	(590) Mr. M. A. Pasha .	Manganese . .	P. L. .	87	28th April 1918.	Do.
Do. .	(591) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	114	25th June 1918.	Do.
Do. .	(592) Mr. P. C. Dutt .	Barytes, arsenic, and antimony.	P. L. .	116	13th November 1918.	Do.
Do. .	(593) Diwan Bahadur Ballabhdass Manoolal and Kanahya Lal.	Iron, Copper and silver.	P. L. .	346	8th October 1918.	Do.
Do. .	(594) Mr. P. C. Dutt .	Bauxite . .	P. L. .	442	13th November 1918.	Do.
Nagpur .	(595) Messrs. A. H. Wasudeo Rao and A. Damodhar Rao.	Manganese . .	P. L. .	76	21st February 1918.	Do.
Do. .	(596) Messrs. Radhakisan Bros.	Do. . .	P. L. .	31	2nd February 1918.	Do.
Do. .	(597) Nagpur Manganese Mining Syndicate.	Do. . .	M. L. .	39	3rd January 1918.	5 years.
Do. .	(598) Messrs. Bahmansha Fouzdar Bros.	Do. . .	P. L. .	28	21st February 1918.	1 year.
Do. .	(599) Messrs. Lalbehari and Ramcharan.	Do. . .	P. L. (renewal.)	72	18th January 1918.	6 months.
Do. .	(600) Messrs. Bahmansha Fouzdar Bros.	Do. . .	P. L. .	5	16th March 1918.	1 year.
Do. .	(601) Do. . .	Do. . .	P. L. .	33	21st February 1918.	Do.
Do. .	(602) Messrs. Ramprasad and Lakshminarayan.	Do. . .	P. L. .	10	2nd Febraury 1918.	Do.
Do. .	(603) Mir Aslam Khan .	Do. . .	P. L. .	38	30th March 1918.	Do.
Do. .	(604) Do. . .	Do. . .	P. L. .	20	31st March 1918.	Do.
Do. .	(605) Do. . .	Do. . .	P. L. .	37	16th March 1918.	Do.
Do. .	(606) Central India Mining Co., Ltd.	Do. . .	P. L. .	26	28th January 1918.	Do.
Do. .	(607) Mr. Lakshman Damodhar Lele.	Do. . .	P. L. .	537	7th February 1918.	Do.
Do. .	(608) Indian Manganese Co., Ltd.	Do. . .	P. L. .	57	13th February 1918.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur	(609) Indian Manganese Co., Ltd.	Manganese	P. L.	24	16th March 1918.	1 year.
Do.	(610) Nagpur Manganese Mining Syndicate.	Do.	P. L.	17	30th May 1918.	Do.
Do.	(611) Do.	Do.	P. L.	10	13th April 1918.	Do.
Do.	(612) Do.	Do.	P. L.	16	29th June 1918.	Do.
Do.	(613) Do.	Do.	P. L.	69	13th April 1918.	Do.
Do.	(614) Messrs. Radhakisan & Bros.	Do.	P. L.	66	Do.	Do.
Do.	(615) Do.	Do.	P. L.	21	28th May 1918.	Do.
Do.	(616) Do.	Do.	P. L.	6	8th May 1918	Do.
Do.	(617) Do.	Do.	P. L.	34	29th June 1918.	Do.
Do.	(618) Mr. M. B. Dadabhoy, C.I.E.	Do.	P. L.	28	30th June 1918.	Do.
Do.	(619) Rai Bahadur Bisesardas Daga & Bros.	Do.	M. L.	133	8th May 1918	5 years.
Do.	(620) Do.	Chrome apatite, phosphate, etc.	P. L.	268	23rd May 1918.	1 year.
Do.	(621) Messrs. Lalbehari Narayandas and Ramcharan Shankerlall.	Manganese	P. L.	424	19th April 1918.	Do.
Do.	(622) Do.	Do.	P. L.	8	29th June 1918.	Do.
Do.	(623) Messrs. Goredut Ganeshlal and M. D'Costa.	Do.	P. L.	34	17th May 1918.	Do.
Do.	(624) Messrs. Bahmansha Fousdar Bros.	Do.	P. L.	56	4th April 1918	Do.
Do.	(625) Do.	Do.	P. L.	78	28th May 1918.	Do.
Do.	(626) Khan Bahadur Byramji Pestonji.	Do.	P. L.	74	27th April 1918.	Do.
Do.	(627) Mir Aslam Khan	Do.	P. L.	84	18th May 1918.	Do.
Do.	(628) Do.	Do.	P. L.	111	Do.	Do.
Do.	(629) Do.	Do.	P. L.	152	30th May 1918.	Do.
Do.	(630) Do.	Do.	P. L.	581	Do.	Do.
Do.	(631) Do.	Do.	P. L.	213	18th May 1918.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(632) Mir Aslam Khan .	Manganese . .	P. L. .	15	30th May 1918.	1 year.
Do. .	(633) Do. . .	Do. . .	P. L. .	18	30th June 1918.	Do.
Do. .	(634) Indian Manganese Co.	Do. . .	P. L. .	219	18th May 1918.	Do.
Do. .	(635) Do. . .	Do. . .	P. L. .	54	Do. .	Do.
Do. .	(636) Do. . .	Do. . .	P. L. .	80	Do. .	Do.
Do. .	(637) Do. . .	Do. . .	M. L. .	21	16th May 1918.	10 years.
Do. .	(638) Messrs. Ramprasad and Lakshmi Narayan.	Do. . .	M. L. .	5	23rd March 1918.	5 years.
Do. .	(639) Mr. N. Venkat Ramannah.	Do. . .	P. L. .	111	28th May 1918.	1 year.
Do. .	(640) Central India Mining Co., Ltd.	Do. . .	M. L. .	5	14th May 1918.	Will expire with the original lease dated the 17th January 1905, to which it is supplementary.
Do. .	(641) Do. . .	Do. . .	P. L. .	155	16th May 1918.	1 year.
Do. .	(642) Nagpur Manganese Mining Syndicate.	Do. . .	P. L. .	142	30th September 1918.	Do.
Do. .	(643) Do. . .	Do. . .	P. L. (renewal.) .	53	20th July 1918.	Do.
Do. .	(644) Mr. Lakshman Rao Damodar Lele.	Do. . .	P. L. .	191	30th July 1918.	Do.
Do. .	(645) Mr. Lakshman Damodar Lele.	Do. . .	P. L. .	73	15th August 1918.	Do.
Do. .	(646) Do. . .	Do. . .	P. L. .	16	Do. .	Do.
Do. .	(647) Do. . .	Do. . .	P. L. .	7	30th September 1918.	Do.
Do. .	(648) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	M. L. .	10	29th June 1918.	5 years.
Do. .	(649) Do. . .	Chrome, apatite and phosphate.	P. L. .	500	30th July 1918.	1 year.
Do. .	(650) Do. . .	Do. . .	P. L. .	299	Do. .	Do.
Do. .	(651) Rai Bahadur Bissesardas Daga.	Do. . .	P. L. .	111	Do. .	Do.
Do. .	(652) Do. . .	Manganese . .	P. L. .	219	Do. .	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(653) Mr. T. Cooverji Bhoja.	Manganese . .	P. L. .	99	30th September 1918.	1 year.
Do. .	(654) Do. . . .	Do. . .	P. L. .	38	15th July 1918.	Do.
Do. .	(655) Do. . .	Do. . .	P. L. .	26	30th September 1918.	Do.
Do. .	(656) Messrs. Radhakisan & Bros.	Do. . .	P. L. .	10	27th August 1918.	Do.
Do. .	(657) Do. . .	Do. . .	P. L. .	81	Do. .	Do.
Do. .	(658) Mir Aslam Khan .	Do. . .	P. L. .	192	28th August 1918.	Do.
Do. .	(659) Do. .	Do. . .	P. L. .	600	30th July 1918.	Do.
Do. .	(660) Do. . .	Do. . .	P. L. .	165	28th August 1918.	Do.
Do. .	(661) Do. . .	Do. . .	P. L. .	33	30th July 1918.	Do.
Do. .	(662) Do. .	Do. . .	P. L. .	227	Do. .	Do.
Do. .	(663) Do. . .	Do. . .	P. L. .	52	Do. .	Do.
Do. .	(664) Central India Mining Co.	Do. . .	P. L. .	331	4th July 1918	Do.
Do. .	(665) Do. . .	Wolfram . .	P. L. .	403	3rd August 1918.	Do.
Do. .	(666) Do. . .	Manganese . .	P. L. (renewal.) .	544	27th April 1918.	Do.
Do. .	(667) Messrs. Bahmansha Fouzdar Bros.	Do. . .	P. L. .	143	8th August 1918.	Do.
Do. .	(668) Do. . .	Do. . .	P. L. .	14	Do. .	Do.
Do. .	(669) Do. . .	Do. .	P. L. .	2	10th October 1918.	Do.
Do. .	(670) Mir Aslam Khan .	Manganese and mica.	P. L. .	533	26th November 1918.	Do.
Do. .	(671) Messrs. Radhakisan & Bros.	Manganese . .	P. L. .	24	21st December 1918.	Do.
Do. .	(672) Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. .	57	29th October 1918.	Do.
Do. .	(673) Mir Aslam Khan .	Mica . . .	P. L. .	493	16th November 1918.	Do.
Do. .	(674) Do. . .	Manganese . .	P. L. .	227	30th November 1918.	Do.
Do. .	(675) Do. . .	Do. . .	P. L. .	78	Do. .	Do.
Do. .	(676) Messrs. Bahmansha Foujdar Bros.	Do. . .	P. L. .	61	20th December 1918.	Do.

P. L.=*Prospecting License.*

CENTRAL PROVINCES—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(677) Mir Aslam Khan .	Manganese .	P. L. .	600	30th November 1918.	1 year.
Do. .	(678) Messrs. Goreduti Ganeshlal and M. D'Costa.	Do. . .	P. L. .	96	11th December 1918.	Do.
Do. .	(679) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	13	26th October 1918.	Do.
Do. .	(680) Messrs. Radhakisan & Bros.	Do. . .	P. L. .	109	21st December 1918.	Do.
Do. .	(681) Rao Sahib D. Lakshminarayan.	Do. . .	P. L. .	174	16th December 1918.	Do.
Do. .	(682) Do. . .	Do. . .	P. L. .	49	15th December 1918.	Do.
Do. .	(683) Do. . .	Do. . .	P. L. .	198	16th December 1918.	Do.
Saugor .	(684) Rao Bahadur Damodar Ramchandra Shrikhande.	Gold and copper .	P. L. .	32	5th January 1918.	Do.
Do. .	(685) Lala Prag Narain .	Iron, pyrites, coal, mineral oil, copper, gold, silver, graphite and antimony.	P. L. .	803	17th June 1918.	Do.
Seoni .	(686) Khan Bahadur Byramji Pestonji.	Manganese . .	P. L. .	269	7th December 1918.	Do.
Yeotmal .	(687) Rai Bahadur Bisesardas Daga.	Coal . . .	M. L. .	2,717	28th October 1918.	30 years.

MADRAS.

Anantapur .	(688) Mr. A. Ghose .	All minerals except precious stones and metals, petroleum and coal.	P. L. .	56·90	9th February 1918.	1 year.
Bellary .	(689) Messrs. Cursetjee Muncharjee's Sons, Bombay.	Red earth . .	P. L. .	853·51	22nd May 1918.	Do.
Do. .	(690) Do. . .	Black earth .	P. L. .	1,298·88	Do. .	Do.
Coimbatore.	(691) Messrs. Startin & Co., Ltd., London, through their Agents The South Indian Export Co., Ltd.	Mica . . .	P. L. .	4·37	18th September 1918.	Do.
Do. .	(692) Do. . .	Do. . .	P. L. .	9·34	Do. .	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

MADRAS—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kurnool .	(693) Mr. A. Ghose .	Barytes and zinc ores.	P. L. .	97	11th August 1918.	1 year.
Do. .	(694) M. R. Ry. B. P. Sesha Reddi.	Barytes . .	P. L. .	11·12	28th October 1918.	Do.
Do. .	(695) Do. . .	Do. . .	P. L. .	12·66	Do. .	Do.
Do. .	(696) Do. . .	Do. . .	P. L. .	42·15	8th November 1918.	Do.
Do. .	(697) Do. . .	Do. . .	P. L. .	7·80	Do. .	Do.
Do. .	(698) Do. . .	Do. . .	P. L. .	2·41	Do. .	Do.
Nellore .	(699) N. Veeraraghavayya.	Mica . . .	P. L. .	49·25	28th February 1918.	Do.
Do. .	(700) P. Venkataswami Chetti.	Do. . .	P. L. .	15·04	3rd January 1918.	Do.
Do. .	(701) G. Venkatachalam Chetti.	Do. . .	P. L. .	9·62	21st February 1918.	Do.
Do. .	(702) P. Venkataswami Chetti.	Do. . .	P. L. .	18·58	Do. .	Do.
Do. .	(703) Kandamur Venkatasubbiah.	Do. . .	M. L. .	362·67	15th October 1916.	30 years.
Do. .	(704) V. K. M. K. R. Karuppan Chetti.	Do. . .	P. L. .	13·65	25th May 1918	1 year.
Do. .	(705) Do. .	Do. . .	P. L. .	6·09	17th May 1918	Do.
Do. .	(706) Mungamoor Subba Rao.	Do. . .	P. L. .	17·35	9th April 1918	Do.
Do. .	(707) G. Venkatachalam Chetti.	Do. . .	P. L. .	48·42	10th April 1918.	Do.
Do. .	(708) G. Venkatasubba Reddi.	Do. . .	P. L. .	43·30	4th April 1918	Do.
Do. .	(709) N. Raghavulu Naicker.	Do. . .	M. L. .	78·56	4th March 1918.	30 years.
Do. .	(710) Messrs. Badsa Sahib & Co.	Do. . .	M. L. .	30·35	27th June 1918.	27 years.
Do. .	(711) V. Venkatasubbayya Nayudu.	Do. . .	P. L. .	32·04	24th September 1918.	1 year.
Do. .	(712) N. Raghavalu Nayakar.	Do. . .	P. L. .	37·40	12th July 1918.	Do.
Do. .	(713) Messrs. F. F. Chrestien & Co.	Do. . .	M. L. .	3·64	28th November 1916.	30 years.
Do. .	(714) Messrs. Startin & Co.	Do. . .	P. L. .	10·60	16th October 1918.	1 year.
Salem .	(715) Messrs. Startin & Co., Ltd., London, managed by their Agents The South Indian Export Co., Ltd., Madras.	Do. . .	M. L. .	29·55	4th February 1916.	30 years.
Do. .	(716) Do. .	Do. . .	M. L. .	64·02	Do. .	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

PUNJAB.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Shahpur .	(717) Khan Bahadur Nasar Woojee and Malikludhan Singh.	Coal . . .	P. L. .	18·37	16th April 1918.	1 year.
Do. .	(718) Attock Oil Co., Ltd.	Mineral oil .	P. L. .	1,920	9th August 1918.	Do.
Do. .	(719) Khan Bahadur Nasarwanji, J. Jamasji, Malik Mohon Singh, Khan Bahadur Seth Adamji Mamooji, Lala Ram Das, Lala Radha Kishen and Lala Amar Nath.	Coal . . .	M. L. .	1,737·75	20th July 1916.	30 years.

SUMMARY.

Province.	Prospecting Licenses.	Mining leases.	Total of each Province.
Assam	7	..	7
Baluchistan	3	1	4
Bihar and Orissa	30	12	42
Bombay	4	..	4
Burma	401	5	406
Central Provinces	205	19	224
Madras	23	6	29
Punjab	2	1	3
Total of each kind and Grand total 1918 . .	**675**	**44**	**719**
TOTAL for 1917 .	515	59	574

CLASSIFICATION OF LICENSES AND LEASES.

TABLE 36.—*Prospecting Licenses and Mining Leases granted in Assam during 1918.*

DISTRICT.	1918.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Cachar	6	26,816·4	Mineral oil.
Sylhet	1	3,136	Do.
TOTAL	7	..	

TABLE 37.—*Prospecting Licenses and Mining Leases granted in Baluchistan during 1918.*

DISTRICT.	1918.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Kalat	3	58,240	Oil.
Mining Leases.			
Bolan Pass	1	244	Coal and coal dust.

TABLE 38.—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during 1918.*

DISTRICT.	1918.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Hazaribagh	14	29,704·56	Mica.
Palamau	1	640	Graphite.
Santal Parganas	5	17·13	Coal.
Singhbhum	1	2,120	Gold.
Do.	2	719·38	Manganese.
Do.	4	6,304	Manganese and iron.
Do.	1	11·90	Yellow ochre.
Do.	1	4,761·6	Iron.
Do.	1	1,600	Chromite.
TOTAL	30	...	
Mining Leases.			
Hazaribagh	4	336·05	Mica.
Singhbhum	2	69·18	Yellow ochre.
Do.	1	143·66	Chromite.
Do.	1	573	Manganese.
Do.	3	5,177·6	Iron and manganese.
Do.	1	150	Gold.
TOTAL	12	...	

TABLE 39.—*Prospecting Licenses and Mining Leases granted in Bombay during 1918.*

DISTRICT.	1918.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Belgaum	1	1,087·4	Bauxite (Aluminium ore).
Dharwar	1	1,143	Galena.
Kaira	1	301·95	Manganese and aluminium.
Sukkur	1	6,008	Mineral oil.
TOTAL	4	...	

TABLE 40.—*Prospecting Licenses and Mining Leases granted in Burma during 1918.*

DISTRICT.	1918.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Akyab	1	1,280	Mineral oil.
Amherst	34	23,876	All minerals (except oil).
Henzada	2	5,235·52	Do.
Do.	1	1,006·5	Coal.
Katha	1	2,752	Gold.
Do.	2	4,370·40	All minerals (except oil).
Do.	1	1,331·20	Wolfram, silver, tin, gold, copper and zinc.
Do.	1	3,200	Gold, copper, iron, silver, lead and wolfram.

TABLE 40.—*Prospecting Licenses and Mining Leases granted in Burma during 1918*—contd.

DISTRICT.	1918.		
	No.	Area in acres.	Mineral.
Prospecting Licenses—*contd.*			
Kyaukse	2	4,533·16	All minerals (except oil).
Lower Chindwin	3	2,940	Do.
Do.	1	640	Mineral oil.
Magwe	4	8,867·3	Do.
Mandalay	2	10,240	All minerals (except oil).
Mergui	35	26,424	Do.
Do.	2	989·44	Tin.
Do.	14	11,088·04	Wolfram and tin.
Do.	1	517·12	Tin and tungsten ores.
Do.	2	3,266·56	Wolfram.
Do.	1	25·37	Tin and allied minerals.
Minbu	9	5,471·12	Mineral oil.
Do.	1	640	Coal.
Myingyan	5	5,213·4	Mineral oil.
Myitkyina	1	1,132·8	Gold and platinum.
Northern Shan States	2	3,200	Iron ore.
Do.	2	5,760	Coal.
Pakokku	2	1,440	Mineral oil.
Do.	1	3,840	All minerals (except oil).
Pegu	1	2,534·40	Do.
Prome	1	320	Mineral oil
Ruby Mines	3	5,161	Mica.
Do.	1	640	Copper.
Salween	1	3 840	All minerals (except oil).
Shwebo	1	1,068·8	Do.
Do.	3	11,744	Mineral oil.
Southern Shan States	2	10,235	Wolfram.
Do.	16	18,508·13	All minerals (except oil.
Do.	2	2,019	Coal.
Do.	1	160.	Antimony.
Tavoy	146	91,048	All minerals (except oil).
Thaton	40	51,549	Do.
Do.	1	2,073·6	Wolfram.
Thayetmyo	10	34,172·15	Mineral oil.
Do.	3	2,560	Coal.
Upper Chindwin	2	1,600	Mineral oil.
Yamethin	6	5,145·6	Wolfram.
Do	24	35,571·2	All minerals (except oil)
Do	1	3,187·2	Tin.
Do.	3	6,041·6	Lead.
TOTAL	401	..	

TABLE 40.—*Prospecting Licenses and Mining Leases granted in Burma during 1918*—contd.

DISTRICT.	1918.		
	No.	Area in acres.	Mineral.
Mining Leases.			
Magwe	1	1,764·4	Mineral oil.
Mergui	1	2,896·72	All minerals (except oil).
Minbu	1	320	Mineral oil.
Pakokku	1	640	Do.
Tavoy	1	308·92	All minerals (except oil)
TOTAL	5	..	

TABLE 41.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during 1918.*

DISTRICT.	1918.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Balaghat	46	6,354	Manganese.
Do.	35	12,933	Bauxite.
Do.	2	170	Mica.
Betul	2	2,952	Graphite.
Do.	1	83	Coal and Graphit
Do.	1	514	Coal.
Bhandara	6	711	Manganese
Do.	4	165	Corundum.
Chanda	2	4,966	Lead.
Do.	1	614	Lead and antimony
Do.	5	864	Coal.

TABLE 41.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during 1918*—contd.

DISTRICT.	1918.		
	No.	Area in acres.	Mineral.
Prospecting Licenses—*contd.*			
Chhindwara	1	401	Manganese.
Do.	5	2,012	Coal.
Jubbulpore	3	331	Manganese.
Do.	1	1,673	Coal.
Do.	1	95	Iron and felspar.
Do.	1	116	Barytes, arsenic and antimony.
Do.	1	346	Iron, copper and silver.
Do.	1	442	Bauxite.
Nagpur	76	8,672	Manganese.
Do.	1	268	Chrome, apatite, phosphate, etc.
Do	1	403	Wolfram.
Do.	1	533	Manganese and mica.
Do.	1	493	Mica.
Do.	3	910	Chrome, apatite, phosphate.
Saugor	1	32	Gold and copper.
Do.	1	803	Iron, pyrites, coal, mineral oil, copper, gold, silver, graphite and antimony.
Seon	1	269	Manganese.
TOTAL	205	..	
Mining Leases.			
Balaghat	9	1,105	Manganese.
Bhandara	2	48	Do.
Jubbulpore	1	5	Do.
Nagpur	6	213	Do.
Yeotmal	1	2,717	Coal.
TOTAL	19	..	

TABLE 42.—*Prospecting Licenses and Mining Leases granted in Madras during 1918.*

DISTRICT.	1918. No.	1918. Area in acres.	1918. Mineral.
Prospecting Licenses.			
Anantapur	1	56·90	All minerals except precious stones and metals, petroleum and coal.
Bellary	1	853·51	Red earth.
Do.	1	1,298·88	Black earth.
Coimbatore	2	13·71	Mica.
Kurnool	1	97	Barytes and zinc ores.
Do.	5	76·14	Barytes.
Nellore	12	301·34	Mica.
TOTAL	23	..	
Mining Leases.			
Nellore	4	475·22	Mica.
Salem	2	73·57	Do.
TOTAL	6	..	

TABLE 43.—*Prospecting Licenses and Mining Leases granted in the Punjab during 1918.*

DISTRICT.	1918. No.	1918. Area in acres.	1918. Mineral.
Prospecting Licenses.			
Shahpur	1	18·37	Coal.
Do.	1	1,920	Mineral oil.
TOTAL	2	..	

TABLE 43.—*Prospecting Licenses and Mining Leases granted in the Punjab during 1918*—contd.

DISTRICT.	1918.		
	No.	Area in acres.	Mineral.
Mining Leases.			
Shahpur . . .	1	1,737·75	Coal.

THE GASTROPOD FAUNA OF OLD LAKE-BEDS IN UPPER BURMA. BY N. ANNANDALE, D.SC., F.A.S.B., *Zoological Survey of India.* (With Plates 31 to 33).

IT has often struck me in examining the living freshwater molluscs of the Indian Empire that it would be of great advantage to learn something by practical experience of the fossil shells of the same area. An opportunity to do so has now been granted me by the kindness of Dr. H. H. Hayden, F.R.S., Director of the Geological Survey of India, who has placed at my disposal the rich collection of fossils in his charge. I have also to thank Mr. E. Vredenburg and Mr. G. H. Tipper of the same department for information about the beds in which the specimens were found and the literature upon them. I am particularly indebted to Mr. Vredenburg in this respect.

I.—PARALLEL EVOLUTION IN THE VIVIPARIDÆ AND HYDROBIIDÆ.

(Plate 31.)

I have selected the Burmese specimens of lacustrine origin in the collection as the first to examine, because they illustrate a phenomenon to which I have recently devoted much attention in the living species of the same country, namely the fact of parallel evolution or convergence on a large scale in the shells of the freshwater Gastropod fauna of different regions and epochs. In the Tertiary and Pleistocene beds of Upper Burma and the Shan States the most conspicuous, and apparently one of the most abundant, genera was the peculiar offshoot of the Viviparidæ for which I have recently coined the name *Taia* in allusion to the Tai or Shan race in whose country it was evolved and proliferated. Moreover, specimens from these beds fully bear out my view,[1] that the evolution in Burmese lakes of Viviparidæ with peculiar ridged, nodulose and even spiny shells is exactly parallel to, but quite independent

[1] Annandale, *Rec. Ind. Mus.*, XIV, pp. 159—168, 202 (1918).

of, that which produced *Margarya* [1] in the lakes of south-western China, and also of that which, at an earlier period and in a distant country, resulted in a large series of species of *Vivipara* or *Tulotoma* [2] with a similar type of shell in the Vienna Basin. The resemblance is so close that it almost appears specific in some instances, practically the only difference being that the European shells have fewer spiral ridges than the Chinese and are smaller. It can hardly be maintained, however, that *Margarya* is genetically related, great as is the similarity of the shells, to the Viviparidæ described by Neumayr (*op. cit.*) and Penecke [3] from Tertiary beds in the old Austrian Empire, or by Forbes [4] from the island of Cos; for *Margarya*, the shell of which is unusually thick and therefore capable of preservation, is a genus islolated geographically; several apparently extinct fossil or subfossil forms are known from western China, but none older than Quaternary, and among recent and sub-recent shells from Yunnan and the neighbouring districts we find, as we also do in the Vienna Basin, a complete transition between normal Viviparidæ and highly sculptured forms, but the line of descent is not the same in the two series. *Taia*, again, is proved by the peculiar structure of its columellar callus to have arisen independently of both Austrian and Chinese forms. It is closely analogous to, but not homologous with, them, and the ultimate products of its line of evolution possess in themselves clearer evidence of an independent ancestry.

The genus *Vivipara* has, in fact, again and again, in diverse countries and at different periods, manifested, when left undisturbed and isolated for longer periods, a tendency to produce shells ornamented with smooth spiral ridges. With further evolution these ridges become at first undulated on the surface, then granular or nodular, and finally in a few instances (*e.g.*, the living *Taia intha* and some forms of *Margarya melanoides*) are transformed into series of peculiar squamose spines.

Moreover, *Vivipara* is not the only genus in which this tendency appears. It is shown to some extent by the Neritidæ of Tertiary beds in Cos (Forbes, *loc. cit.*) and in a more striking manner by the Hydrobiidæ or Paludestrinidæ of the same period and region

[1] Dautzenberg & Fischer, *Journ. de Conchyl.*, LIII, p. 420 (1905).
[2] Neumayr, *Abh. k. k. Geol. Reichsanstalt*, VII (3), p. 50 (1875).
[3] Penecke, *Beitr. Paläont. Osterreich-Ungarns*, IV, p. 26 (1886).
[4] Forbes, *Edin. New. Phil. Journ.*, XLII, pp. 273, pl. iii (1847).

and by those still living in the Yangtse valley. In the Yangtse valley of to-day there are, indeed, three genera of this family which have the same type of shell as the Viviparidæ discussed above, and which, on conchological evidence alone, can be distinguished from genera that flourished in the Vienna Basin in Miocene times only by apparently trivial characters. These genera, to give them their palæontological names, are *Fossarulus*, *Prososthenia* and *Tylopoma.*

The literary history of *Fossarulus* is interesting. The genus was described in 1869 by Neumayr [1] with a fossil shell (*F. stachei*) from Miocene beds in Dalmatia as type. In 1883 the same author [2] referred to the genus several recent species from China; two of these he subsequently figured [3] (1890). A year later Nevill [4] in his *Hand List of Mollusca in the Indian Museum* mentioned a living Indian species as "*Bythinia* (*Fossarulus ?*) *marginata.*" This species Godwin-Austen [5] has just redescribed, placing it in a new genus (*Mysoria*) and showing that it has no real relationship to the fossil *Fossarulus*. In a preliminary examination of the Inter-trappean fossils from Nagpur I have been much struck by the resemblance between Hislop's [6] *Valvata multicarinata* and *Mysoria*, to which I suspect that it will ultimately have to be assigned. I have not seen the Chinese species assigned to *Fossarulus*, or any fossil form; but the figures do not seem to me to provide conclusive proof of generic identity, for the structure of the lip of the shell is distinctly different.

The history of *Prososthenia* is very similar and will be found in the same works; a species allied to the recent Chinese one occurs in the Namma beds and will be discussed later. The record of *Tylopoma* is still more complicated. Brusina [7] originally described the genus, on the basis of shell and operculum, in a foot-note to his paper on *Orygoceras* in certain beds of the old Austrian Empire. The type-species was a Miocene fossil from the Vienna Basin, which

[1] Neumayr, *Jahrb. K. K. Geol. Reichsanstalt*, XIX, p. 361 (1869).
[2] Neumayr, *Neues Jahrb. Min. Geol. Pal.*, II, p 23 (1883).
[3] Neumayr, *Sussw. Moll.* in *Wiss. Ergebn. Reis. Bela Szechenyi*, II, p. 653 (1890).
[4] Nevill, *Hand List Moll. Ind. Mus.*, II, p. 42 (1884).
[5] Godwin-Austen, *Rec. Ind. Mus.*, XVI, p. 209 (1919). The name has had to be changed to *Mysorella*, as *Mysoria* is preoccupied in insects. A note on the subject will be published by Col. Godwin-Austen in the next number of the *Rec. Ind. Mus.*
[6] Hislop, *Proc. Geol. Soc.*, XVI, p. 170, pl. v, figs. 15*a*, 15*b* (1859). The figures are poor.
[7] Brusina, *Beitr. Pal. Osterreich-Ungarns*, II, p. 73 (1882).

Brusina, and also Neumayr, assigned to the Viviparidæ. I have recently described[1] as a new genus a living mollusc from the Tai Hu (lake) in the Kiangsu province, China, which is certainly, on anatomical grounds, a Hydrobiid, but (or a very closely allied form) has been confused with a common Chinese species of *Vivipara* by such authorities as Möllendorf and Kobelt. This genus, which I have called *Pseudovivipara,* could be distinguished, but only just distinguished, generically on *shell-characters alone* from the fossil European *Tylopoma.* Yet a fourth genus of the same family (*Oncomelania*) still lives in the Yangtse valley and closely resembles Miocene Dalmatian species. I shall have to discuss this genus later, for there are fossil species from Upper Burma.

Either these instances of resemblance between the shells of Miocene Gastropods from eastern Europe and recent Gastropods from eastern Asia are instances of convergence or parallel evolution, or else the resemblance is due to the Asiatic forms being actual survivors, or rather the descendants of survivors, of the Miocene fauna of the Vienna Basin. In the Viviparidæ the case for the former alternative is complete: in the Hydrobiidæ it is almost equally strong. Whatever the explanation may be, however, the facts give a warning as to the use of fossils from freshwater beds in identifying horizons. From the instances adduced above, and from many others that might be cited, it seems that freshwater fossiliferous beds can be divided into two classes, those in which the shells of the Gastropods (other than Melaniidæ) are mostly smooth, and those in which they are frequently ornamented with a strong spiral sculpture. Those beds in which most of the shells are smooth have a fauna consisting of species and genera likely to have had a wide geographical range and to afford clear evidence of their natural affinities. Beds,[2] on the other hand, in which a large proportion of the species, or even of the individuals, of the Gastropod molluscs have the shells ornamented deeply with spiral sculpture represent a highly specialized fauna that has probably originated locally and proliferated in a limited area, in which affinities are likely to be disguised by secondary modifications. As examples of a fauna of the first type I may instance that of the Paris Basin[3]

[1] Annandale, *Mem. As. Soc. Bengal,* VI, p. 309 (1918).
[2] I refer of course only to lacustrine, not to marine or estuarine beds.
[3] See Cossmann & Pissaro, "*Icon. comp. Coquilles Fossiles de l'Eocine des Environs de Paris* II, (1910—1913).

or the living freshwater fauna of Europe,[1] Japan[2] or Peninsular India[3]; as examples of the second type, the existing fauna of Lake Tanganyika,[4] of the lakes of Celebes[5] and the Yangtse valley,[6] or the fossil fauna of the Vienna Basin[7] or of the lake-beds of Upper Burma. I cannot give a precise statement as to the physical conditions in which a fauna of this second type is habitually evolved, but that the conditions have been similar in different countries and epochs there can be little doubt, and three factors seem to be of importance. These are (1) a district with many lakes in the process of waning rather than waxing; (2) water containing abundant mineral salts, probably of sodium and magnesium as well as of calcium, and (3) a temperate climate in which there is never extreme cold. I am inclined personally to lay great stress on the chemical factor as providing a stimulus for evolution in this direction.

II.—THE GASTROPOD FAUNA OF VARIOUS LAKE-BEDS IN UPPER BURMA.

The Pleistocene and Tertiary freshwater Gastropod shells from Upper Burma in the collection of the Geological Survey of India are from two widely separated districts and belong to two different periods. A large number of specimens are from the clay beds associated with the Namma coal-fields in the Northern Shan States, while others are from the ferruginous conglomerate beds at Yenangyat near the oil-fields of Upper Burma.

The age of the Namma bed is a little uncertain, but La Touche[8] is of the opinion that they are Pleistocene.. The shells, which are soft and decayed, are preserved in a clay that appears to be of lacustrine origin. The largest and most conspicuous shells in these beds belong to the genus *Taia* and represent two species, one of

[1] See Rossmässler's *Icon. Land-u.-Süssw.-Mollusken* (*passim*).

[2] See Kobelt. "Faun. Japon. Extramarina" in *Abh. Senckenber. Nat. Ges.*, XI (1879).

[3] See Hanley & Theobald, *Conchologia Indica* (1876).

[4] See for figures and descriptions (*not* for theory) Moore, *The Tanganyika Problem* (London: 1903).

[5] See P. & F. Sarasin, *Die Süssw. Mollusken von Celebes* (*Weisbaden*: 1898).

[6] See Heude on the freshwater Mollusca in *Mém. l'Hist. Nat. Empire Chinois*, I (1880—1890).

[7] See Paul & Neumayr, "Die Congerien und Paludinenschichten Slavoniens und deren Faunen," *Abh. K. K. Geolog. Reichsanstalt*, VII (3), pp. 1—106, (1875); also Penecke "Beit. Zur Kenntniss Der Fauna der Slavonischen Paludinenschichten", *Beit. Pal. Ost-reich Ungarns*, IV (Wein, 1886).

[8] La Touche, *Mem. Geol. Surv. Ind.*, XXIX, p. 321 (1913).

which I cannot distinguish from the living *Taia naticoides*, the type-species of the genus. This is a mollusc of extraordinary individual variability; some individuals can hardly be distinguished from *Taia theobaldi*, which is perhaps the most primitive and least modified species of the genus, while others have the characteristic sculpture highly developed. *T. naticoides* has not hitherto been found in a fossil state, but I have always regarded it as the parent form of most species in the genus.

Also in the Namma beds, but in much greater abundance and in clay of rather a different character, there is a very remarkable shell which must also be referred to *Taia* but to a distinct subgenus. I propose for it the name *Taia (Crassitaia) infracrassata*, sp. et subgen. nov. It is remarkable for its thickness, for its squat though pointed form, for the curious flattening of the base of the body-whorl and the exaggerated development of the columellar callus. As the great breadth and plate-like form of this structure is the most important generic character of *Taia*, *T. infracrassata* must be regarded as having a highly modified shell.

Associated with *T. naticoides* in these beds are at least five species of Hydrobiidæ, three of which I am able to place definitely in their genera and describe specifically. These belong to the interesting genera *Oncomelania* and *Paraprososthenia*, both of which occur living in China, and both of which bear a remarkable but apparently convergent resemblance to species of Miocene age from the Vienna Basin.

In the conglomerate beds of Yenangyat I can only distinguish one species, a member of the same genus *Taia*, but of another new subgenus, *Rivularioides*. The age of these beds is again uncertain, but they are certainly Tertiary, either uppermost Oligocene or uppermost Miocene. They are, therefore, in all probability much older than those of Namma. Their *Taia*, which is very abundant but as a rule considerably worn on the surface, has taken an entirely different line of evolution from that of the Northern Shan beds of clay, being ornamented with greatly elongate blunt processes, but possesses the same generic characters. I believe that it probably lived in a different type of habitat.

It will, I think, be worth while to discuss the fauna of these beds in greater detail before coming to the technical descriptions of species and genera, and to compare it with that of other lake-beds in Upper Burma.

(*a*) Gastropod Fauna of Lake-Basins in the State of Yawnghwe, Southern Shan States.

To appreciate the peculiarities of fossil faunas it seems to me of great importance to study those of living or recently extinct species of the same region and their correlation with peculiarities in environment. This we can do with unusual facility in the Shan States, in which there exists, in the State of Yawnghwe in the southern group, a remarkable series of lake-beds, one of which (the Inle Lake) still contains water, though now shrunken and shallow. Each of these lake-beds had or has its own Gastropod fauna, and it is possible to estimate the type of locality in which each species lived, mainly by a study of the conditions in the existing lake. I have recently (in vol. XIV of the *Records of the Indian Museum*) given a detailed zoological account of the fauna of the Inle Lake and have also discussed the shells of other lake-beds in the district. Here I propose to give for the benefit of geologists a summary of the results achieved in so far as they affect the palæontology of Burma. I may say that the classification and nomenclature adopted is not precisely the same as that of the original paper, for further anatomical investigations, undertaken largely by Dr. Baini Prashad of the Bengal Fishery Department, have made certain changes inevitable.

The dry lake-beds in which fossil and subfossil shells were collected by Dr. F. H. Gravely and myself in the Southern Shan States were two, the He-Ho basin and the Hsin-Dawng valley.

The He-Ho basin is now a marshy plain some 7 miles long by 5 miles broad. It lies at an altitude of 3,800 feet above sea level in lat. 20° 50′ N., long. 96° 42′ E. A considerable part of its area has been cleared for agriculture and consists of red soil derived from the insoluble residue of magnesian limestone[1] and characteristic of both the Northern and the Southern Shan States. There are, however, especially towards the margin of the basin, large deposits of peat and at some places these are traversed by curious little ridges of calcareous tufa that evidently represent recent stream-beds which traversed the swamp after it was nearly dry.

In both peat and tufa shells of Gastropod molluscs are abundant, belonging mostly to species that still live in the neighbourhood and

[1] La Touche, *Mem. Geol. Surv. Ind.*, XXXIX, p. 322 (1913).

often retaining traces of colour and remains of the periostracum, The following species were collected :—

Fam. PLANORBIDÆ.

Planorbis exustus.

Fam. MELANIIDÆ.

Melanoides tuberculata.

Melania (Brotia) baccata subsp. *elongata.*

Fam. HYDROBIIDÆ (=PALUDESTRINIDÆ).

Bithynia (Hydrobioides) nassa subsp. *distoma.*

Fam. VIVIPARIDÆ.

Taia intermedia

Taia lacustris.

Taia analoga.

Of these forms, only the three species of *Taia*, which are all closely related to forms from other lakes or marshes in the neighbourhood, and the subspecies of *Hydrobioides nassa* are extinct.

At its eastern extremity the He-Ho basin narrows considerably and is confined between two limestone ridges. Through the little valley thus formed a small but deep and rather rapid stream, the water of which is almost black owing to the fragments of peaty matter it holds in suspension, makes its way, finally descending through a narrow gorge that it has cut through a ridge of hard limestone, to the Inle basin about 800 feet below. Some distance before reaching this gorge it has excavated a bed in a lacustrine deposit of fine grey clay full of shells, most of which are different from those of the superficial deposits. The exposure is at least twenty feet deep. The molluscs obtained from it are:—

Fam. LIMNÆIDÆ.

Limnæa prox. *ovalis.*

Limnæa shanensis, phase A.

Fam. PLANORBIDÆ.

Planorbis (? Tropidodiscus) trochoideus.

Fam. HYDROBIIDÆ.

Bithynia (Hydrobioides) nassa subsp. *distoma.*

Fam. VIVIPARIDÆ.

Taia lacustris.

Of these species the *Limnæa* near *L. ovalis*, the *Bithynia* and the *Taia* are apparently extinct, while the other *Limnæa* represents a phase slightly different from the living one that occurs in

the district. The *Taia* is very much more abundant than it is in the peat and tufa, in which *T. intermedia* is the dominant form.

Still further down stream in the He-Ho basin, just before the stream plunges into its gorge, there is a third deposit of shells, lying exposed on the bank. This deposit is evidently of mixed origin, containing many shells brought to it by floods, as well as others which died *in situ*. The abundance of *Succinea*, an amphibious genus, and the fact that land-shells (*Plectopylis*) occur in it indicate that it is mainly of marginal origin. The species found in it were :—

Fam. SUCCINEIDÆ.
Succinea indica.
Fam. LIMNAEIDÆ.
Limnæa shanensis, phase B.
Fam. PLANORBIDÆ.
Gyraulus convexiusculus.
Fam. MELANIIDÆ.
Melania (Brotia) baccata subsp. *elongata.*
Fam. HYDROBIIDÆ.
Bithynia (Hydrobioides) turrita.
Bithynia (Hydrobioides) nassa subsp. *distoma.*
Amnicola (Alocinma) alticola.
Fam. VIVIPARIDÆ.
Taia theobaldi.
Taia intermedia.
Taia lacustris.

Most of these species still live in the district, and it is possible that the shells of those which do not do so have been brought by floods. *Bithynia turrita*, orignally described from the banks of the Irrawadi, has never been found in a living condition, but there is no particular reason to regard it as being an extinct form, as it has not been found in abundance. *Taia theobaldi* lives in streams, the other species being still-water forms.

I will defer discussion as to the age of these three deposits until I have considered the living fauna of the Inle Lake. There is, however, one other deposit in the district about which something must be said first.

Some six or seven miles east of the He-Ho basin, on the other side of the Inle basin and slightly to the north, there is a little valley between limestone hills in which the Hsin-Dawng stream

flows down towards the Inle Lake. This valley shows much less obvious signs of having been a lake-bed than the He-Ho basin, but shells of a lacustrine type were found in banks of red soil in a couple of little limestone caves on the eastern side. These shells had evidently been brought into the caves by floods. With them were associated teeth of the Thamin deer (*Cervus eldi*). The species are :—

Fam. MELANIIDÆ.
Melania (*Brotia*) *variabilis* var.

Fam. VIVIPARIDÆ.
Taia theobaldi.
Taia conica.
Taia cylindrica.

The two last species are of a highly modified type, but *Taia conica* is related to forms from both the He-Ho basin and the Inle Lake, while *T. cylindrica* is a more specialized form of the same type as *T. intermedia.* The *Melania,* which also occurs in the Miocene freshwater beds of Pegu, and *Taia theobaldi* are each represented by a single specimen.

The Inle Lake, which lies between the He-Ho basin and the Hsin-Dawng valley, is a solution lake in a limestone basin and its water contains relatively large quantities of salts[1] of sodium, magnesium and calcium. The lake is now very shallow and about 14 miles long by 4 miles broad, but is evidently silting up and must at one time have been much larger and deeper. I have discussed its fauna, which is highly peculiar as to fish as well as molluscs, in the volume already cited, and all that need be done here is to give brief statements as to the Gastropod molluscs which occur, their mode of occurrence and their bearing on the palæontology of ancient lake-beds in Burma.

The lake is divided faunistically into three regions, a Marginal Zone, an Intermediate Zone and a Central Region. The Marginal Zone is remarkable on account of the floating islands of peat and and vegetation with which it is covered, the Intermediate Zone is merely the outer edge (*i.e.*, the edge towards the Central Region) of these islands, while the Central Region is the open lake, which contains water of remarkable clearness. These regions are well

[1] See analysis by R. V. Briggs in *Rec. Ind. Mus.*, XIV, p. 2 (1918).

characterized by the Gastropod fauna. In the Marginal Zone the following species occur:—

Fam. SUCCINEIDÆ.
Succinea indica.

Fam. LIMNÆIIDÆ.
Limnæa andersoniana, pond phase.
Limnæa shanensis, phase C.

Fam. PLANORBIDÆ.
Planorbis (? Tropidodiscus) trochoideus.
Segmentina calathus.
Segmentina cœnosus.

Fam. HYDROBIIDÆ.
Bithynia (Hydrobioides) nassa, s.s.
Bithynia (Hydrobioides) nassa subsp. *lacustris.*
Bithynia (Hydrobioides) nana.
Bithynia (Hydrobioides) physcus.
Amnicola (Alocinma) alticola.

Fam. VIVIPARIDÆ.
Vivipara lecythis.
Taia shanensis.

Fam. AMPULLARIIDÆ.
Pachylabra[1] *winkleyi.*

Most of the species are also found in ponds and marshes, but *Taia shanensis* is apparently endemic.

The Gastropod fauna of the Intermediate Zone of the Inle Lake includes all the species and subspecies found in the Marginal Zone except *Planorbis exustus* and *Limnæa andersoniana,* which apparently do not wander so far from the shore. It also includes the following additional species, *Limnæa mimetica, Gyraulus velifer* and *Taia elitoralis.* The last is peculiar to this zone, while the *Limnæa* and the *Gyraulus* also occur in the Central Region, but are not known from any other locality.

In the Central Region there is among the Gastropods a great abundance of individuals, but a comparative paucity of species. The Pulmonates of the Intermediate Zone occur sparingly; among the Hydrobiids only *Bithynia physcus* and the subspecies *lacustris* of *B. nassa,* the *forma typica* of which is entirely absent, are found,

[1] The name *Ampullaria* must unfortunately be restricted on anatomical grounds to the American forms.

but the two that occur are extremely abundant. There is no Ampullariid, and no true *Vivipara.* The most characteristic species is the single *Taia* (*T. intha*), which is found only in this region and is in many respects the most highly specialized form in its subgenus. *Melania* (*Melanoides*[1]) *tuberculata*, a species of immense geographical range, is only found in this region so far as the lake is concerned.

In the Inle basin several fresh water molluscs that are not found in the lake are common in pools or small streams :—*Taia naticoides* in the former, the stream-phase of *Limnæa andersoniana, Melania* (*Brotia*) *baccata* subsp. *elongata, Melania* (*Brotia*) *terebra* and *Taia theobaldi* in the latter.

The Gastropods of these Yawnghwe lake-beds are not by any means in all cases highly modified forms. The genus *Taia* is, however, the most conspicuous element in each lake, and this genus possesses in an eminent degree the peculiarities referred to above as characteristic of a modified fauna. The Southern Shan species of *Hydrobioides*, moreover, possess the same peculiarities in a rudimentary state and indicate that the fauna has never reached the highest pitch of modification.

From these facts several points of importance to Indian palæontologists are clear. Firstly, each region of the lake, and indeed each type of aquatic environment in the district, has its own species of *Taia.* Secondly, *Vivipara* is rare (only a single dead shell was actually collected) and is not found in lacustrine conditions. Thirdly, in the marginal region of the lake species from swamps and ponds are more abundant than true lacustrine species. It may be further noted that the characteristic of the true lacustrine Pulmonates are thinness and delicacy of shell, lack of pigment, small size and a tendency in *Limnæa* for the spire of the shell to disappear. Shells of this order are not highly sculptured. Shells of the Viviparidæ, on the contrary, reach in lacustrine conditions of the peculiar type a fair or large size, tend to become elongate and have their spiral sculpture very strongly developed and regular. In this respect *Taia intha* surpasses all known species of the family,

[1] On the use of this subgeneric (or generic) name see v. Martens on the freshwater molluscs in vol. IV of Weber's, *Zool. Ergebn. Reise Niederl. Ost-Indien*, p. 50 (1892). The question is further discussed in a report on the Mollusca of Seistan to be published immediately by Dr. Baini Prashad and myself—*Rec. Ind. Mus.*, XVIII, p. 28.

while *T. elitoralis* is also remarkably advanced and *T. shanensis*, though superior to *T. naticoides* and *T. theobaldi*, much less perfect.

Now, if we compare the living Gastropod fauna of the Inle Lake with the partially extinct Gastropod fauna of the old He-Ho Lake several important facts become clear. Most of the species are identical, but those of *Taia* are different, while those of *Limnæa* and *Bithynia* belong in several instances to distinct subspecies or phases. This is exactly the state of affairs that is found in different types of environment among the living fauna of the Inle basin, and, though the He-Ho deposits have been to some extent disturbed, we can find a parallel there also. The exposure towards the east end of the plain represents the Central Region of the lakes, the peaty deposits and calcareous tufa partly the old Marginal Zone and partly a later stage when this zone had been transformed into a regular marsh; while the shells lying at the edge of theream just above its gorge were originally not lacustrine at all, but of a paludine fauna. A comparison of the species of *Taia* fully bears out this view. *T. analoga* from the peat is literally the He-Ho analogue of *T. elitoralis* of the Intermediate Zone of the Inle Lake. This species is much less abundant than *T. intermedia*, which is a slightly modified offshoot of *T. naticoides* (still an abundant species in pools in the basin) but has distinct affinities to *T. shanensis*; while *T. lacustris*, though not very closely related to *T. intha*, resembles it in its more elongate form.

Local traditions seem to point to the fact that the He-Ho Lake may have dried up in historical times. Apart from this, I would, on conchological evidence alone, now rank all the deposits in this basin as recent or subrecent, though that containing *T. lacustris* in abundance must be considerably older than the others.

We have a much less complete record from Hsin-Dawng, but here the occurrence of a variety of *Melania variabilis* gives us something a little more definite, for this variety is also found in abundance in beds of apparently Miocene age in the Pegu district of Lower Burma. Of the three species of *Taia*, *T. theobaldi*, which still survives, lives in streams, while the other two are of distinctly lacustrine type. *T. conica* is very closely allied to the living *T. elitoralis* and the extinct but recent *T. analoga*, while *T. cylindrica* resembles *T. lacustris* but is much more highly modified. In considering a genus so plastic as *Taia* the element of time, as

Vredenburg[1] has pointed out, need have little importance and the fact that one species is more highly modified than another does not necessarily mean that it is more recent. *T. intha*, indeed, is in some respects the most highly modified species—living, Pleistocene or Tertiary—in the genus. The *Melania*, moreover, may have persisted for a long period of time. Taking everything into consideration I am inclined to regard the Hsin-Dawng deposit as more ancient than those of He-Ho, and it may be Pleistocene.

(*b*) The Gastropod Fauna of the Namma Freshwater Beds in the Northern Shan States.

The freshwater beds of the neighbourhood of Namma (lat. 22° 42′ 30″ N., long. 97° 52′ E.) in the Northern Shan States have been described in considerable detail by La Touche, but we naturally possess less information about them than we do about the more recent (or probably more recent) Inle system. They seem to represent a similar series of lakes, none of which were, however, so deep as the Inle Lake once was. The fossils occur in a hard grey or pinkish clay much more coherent than that of the lacustrine deposit of the He-Ho plain and with fewer plant-remains, but otherwise similar. The shells, though their outlines are fairly clear and their shelly substance remains, are fragile and as a rule imperfect. An interesting feature of the deposit is that young, almost microscopic shells can be removed from the clay by soaking it in water. The species represented are, with one exception, distinct from those yet in force elsewhere, as is also a subgenus. The one exception is *Taia naticoides*, the typical form of which is not lacustrine, though the very closely allied *T. intermedia* was apparently an inhabitant of a shallow lake. The Namma fossil shells are not sufficiently well preserved for a very precise determination, and it is possible that they represent a form at least as distinct from the typical *T. naticoides* as *T. intermedia*, which they may have resembled very closely. This understood, I may now give a list of the species :—

Fam. HYDROBIIDÆ.

Oncomelania fragilis, sp. nov.

O. conoidalis, sp. nov.

[1] *Rec. Ind. Mus.* XIV, p. 182 (1918).

Oncomelania sp.
Paraprososthenia minuta, gen. et sp. nov.
? *Amnicola* sp.
Fam. VIVIPARIDÆ.
Taia naticoides.
Taia (*Crassitaia*) *infracrassata*, subgen. et sp. nov.

It is possible that a third species of *Taia* is represented, but the remains are very imperfect. Tipper states that a species of *Hydrobia* occurs in the same deposits, but he probably refers to either the *Paraprososthenia* or a species of *Oncomelania*, many shells of which are represented by casts that do not show the characteristic sculpture.

All the species, except *Taia naticoides* and possibly (but very improbably) the *Amnicola*, are new to science, as is not surprising; but the *Paraprososthenia* and the *Oncomelania* are closely related to species that still live in China, while, as we shall see later, the new subgenus *Crassitaia* affords interesting evidence as to a probable relationship between the surviving Burmese subgenus *Taia* s.s. and the living Chinese genus *Rivularia*.

La Touche is of the opinion that the Namma beds are of Pleistocene origin. The Gastropod fauna provides little evidence of age except in so far as it is highly differentiated and exhibits traces of relationship on the one hand, through *Taia naticoides*, with the existing freshwater fauna of Upper Burma, and on the other, through the remaining species that can be specifically identified, with that of China. Evidence for some connection with the latter country is strong and, as we shall see when discussing the fossils from another part of Upper Burma, is borne out by species of apparently older date. The living freshwater Gastropod fauna of Burma has as a whole affinities both with that of India west of the Bay of Bengal and with that of China, but the relationship of the Namma species with those of the Yangtse is apparently of a more intimate nature than that of living Burmese forms. I say "apparently," because the shells that provide clearest evidence so far as the Namma beds are concerned are minute, and we know as yet comparatively little about the smaller living freshwater Gastropods of Upper Burma.

The clay in which fossils are preserved in the Namma beds is not quite homogeneous. That in which the specimens of *Taia*

infracrassata occur is harder, less readily broken up in water and of a duller grey colour than that in which the *T. naticoides* and the Hydrobiidæ are found. In the latter, moreover, there are more evident traces of plant-remains. This probably indicates that the species are not all from precisely the same type of environment and as *T. naticoides* is known to be a paludine rather than a lacustrine species and the living species of *Oncomelania* are amphibious in habits, it seems probable that both the Viviparid and the Hydrobiids lived in the marginal zone of the lake or lakes they occupied, while *T. infracrassata* inhabited the central region. Its elaborate sculpture is an additional argument for this view.

The shells from these beds, though very fragile, are not at all eroded on the surface.

(c) The Gastropod Fauna of the Conglomerate Beds of Yenangyat.

In the collection of the Geological Survey of India there are numerous specimens of a hard ferruginous conglomerate from beds at Yenangyat (lat. 21° 61′ N., long. 94° 48′ E.) in the district of the Upper Burma oil-fields. Mr. Vredenburg informs me that these beds are of Tertiary origin, but their precise age is uncertain; they may be either uppermost Oligocene or uppermost Miocene.

The specimens are full of the remains of Gastropod shells, but these are mostly in a bad state of preservation and the hardness of the stone renders it impossible to develop them satisfactorily as they are much softer than the matrix. The only species that it has been possible to remove is a very peculiar one, which I assign to the genus *Taia* but to a new subgenus, for which I propose the name *Rivularioides*. The shell of this species (*T. spinifera*, sp. nov.) is ornamented with elongate but apparently blunt spines arranged on the body-whorl in two spiral series. They have a squamose character and are evidently no more than highly developed homologues of the scale-like projections that ornament the shells of certain living species of *Taia*. In other respects the shell exhibits an interesting resemblance to that of the living Chinese genus *Rivularia*, Heude,[1] from the Yangtse valley[2] and suggests a common origin for that genus and *Taia*.

[1] Heude, *Moll. d'Eau Douce, Mém. Hist. Nat. Emp. Chinois*, I, p. 179 (1890).

[2] *Rivularia* is a fluviatile genus (*fide* Heude), and it is possible that the Yenangyat beds are of fluviatile rather than lacustrine origin. Mr. Sethu Rama Rau, who collected the fossils from these beds, tells me that they are continuous with others containing *Batissa kodungensis*, and *Batissa* is an estuarine genus.

III.—DESCRIPTIONS OF SPECIES AND GENERA FROM THE NAMMA AND YENANY AT BEDS.

Fam. Hydrobiidæ.

There is some controversy as to the proper name of this family, which some conchologists call Paludestrinidæ and some Amnicolidæ. I prefer to retain the old well-established name. The family as at present constituted. however, seems to be a somewhat heterogeneous assemblage of genera.

At least five species that must be assigned at any rate provisionally to the family Hydrobiidæ are represented by fossils in the Namma beds. Three belong to the interesting genus *Oncomelania*, one apparently to *Amnicola* and the fifth to the genus here described as *Paraprososthenia*. *Oncomelania* is regarded by Neumayr as synonymous with *Prososthenia*, to which he would assign living species from China as well as certain Miocene fossils from Eastern Europe. I give reasons below for not accepting this view.

Unfortunately two of the species in the Namma clay are not sufficiently well preserved to be described. One is certainly an *Oncomelania*, while I place the other (a minute shell) provisionally in *Amnicola*, Gould and Haldeman, a genus represented by one fairly common species (*A. alticola*, Annandale) in recent and subrecent beds in Yawnghwe.

Genus ONCOMELANIA, Gredler.

1882. *Oncomelania.* Gredler. *Jahrb. deutsch. Malakoz. Ges.* VIII, p. 120.
1887. *Pachydrobia* (in part), Fischer, *Manuel de Conchyliologie*, p. 729.
1890. *Hemibia*, Heude & Rathouis, *Moll. d'Eau douce* in *Mém. l'Hist. Nat. Emp. Chinois* I, p. 167, pl. xxxiii, figs. 1—7, 14—20.
1898. *Prososthenia* (in part), Neumayr, *Süssw. Moll.* in *Wiss. Ergebn. Reise B. Széchenyi in Ostasien*, V, p. 653.

The genus is described as follows by Gredler :—

"*Testa* rimata, turrito-conica, fortiter transverse costata, costis discontinuis, solidula, pellucida. Anfractus valde convexi. Apertura *integra* (haud effusa), oblongo-ovata, minuta. Peristoma continuum aut connexum, circum late sublabiatum, extus *costa fortiori* (varice), reflexa aut tumida, margini parallela *superstructum;* margine externo medio paulo latius, interno supra reflexo."

"*Operculum* corneum, tenue, subspiratum vix differt ab operculo generis Melaniæ."

Heude, who reproduces some excellent figures of the anatomy by Rathouis, places the genus in the Rissoidæ, but his views as to this family and the Hydrobiidæ were not those generally accepted. The structure of the radula is very like that of the radula of *Bithynia*, while the operculum and the male organ resemble those of *Hydrobia*.

A number of living species, the shells of most of which are figured by Heude, occur in the Yangtse system. The type-species (*O. hupensis*, Gredler) was found in Hunan.

Boettger (*fide* Heude) identifies the genus with the Miocene *Fossarulus*, Neumayr, from Dalmatia, while Neumayr himself regards it as synonymous with his *Prososthenia* from the same country and horizon; but Heude pertinently remarks, referring to the opinion of the former writer. "Je ne puis non plus admettre cette détermination, malgré l'autorité du savant qui la propose. En effet, la bouche de l'*Oncomelania* n'est pas notablement rétrécie, ni arrondie; le péristome est réellement simple, et enfin, il n'y les moindres stries coupant les costules nombreuses des tours. Est-il bien démontré d'ailleurs que l'opercule du *Prososthenia* tertiaire soit celui de la coquille Chinoise récente, et son habit est-il dans l'eau douce?" This is equally to the point for Neumayr's identification with *Prososthenia*. The genus is distinguished from *Pachydrobia*, Crosse and Fischer, by the prominent longitudinal sculpture of the shell.

In addition to the two species here described I find traces of a third and possibly a fourth in the same specimens of clay. The larger of these was considerably larger and broader in proportion to its length than any of the described species. The other, which may be the young of *O. fragilis*, is very small.

ONCOMELANIA FRAGILIS, sp. nov.

(Pl. 31, fig. 2; Pl. 32, figs. 5, 5*a*.)

The shells of this species are so fragile that it has been very difficult to develop the specimens sufficiently to enable a full description to be drawn up. I have had to rely not on any one individual, but on characters derived from many separate shells and casts. The outlines, however, are so sharp and the sculpture so clear-cut that less ambiguity arises from this method than might otherwise be the case.

The shell is small, very narrow and elongate, with much the appearance of a small *Melania*, but the structure of the mouth is that described by Gredler and figured by Heude. The ratio of length to breadth is approximately 3 to 1. The apex is sharply pointed and there are 9 whorls, which increase in size very regularly and gradually. The suture is by no means oblique; it is impressed but narrow and is possibly accompanied by a very narrow spiral ridge. There is, however, no transverse constriction of the longitudinal ribs. The whorls are slightly swollen and not at all shouldered above; the body-whorl is a little more swollen than the others and, indeed, has a somewhat contracted appearance. The inner anterior angle of this whorl is slightly produced but broadly rounded. The whorl is about twice the size of the one preceding it, but the increase in size is quite gradual. The mouth of the shell was certainly small and apparently pointed posteriorly; it projected forwards for some distance beyond the body, where the peristome was evidently thickened. A distinct varix can be detected on the outer lip.

Two or three apical whorls were probably smooth but the others are ornamented with prominent longitudinal ribs of a very definite character. There appear to be about 8 to 10 of these ribs on each whorl. Each rib is slightly arched and undercut on the concave side, which is directed towards the mouth of the shell. It has a sharp carina running along its crest and its sides bear several longitudinal striæ. The interspaces between the ribs are deeply concave. They appear to have been smooth and polished but traces of longitudinal striæ can be detected on well-preserved specimens.

Large specimens are about 6 mm. long and 2 mm. broad.

Type-specimen in the collection of the Geological Survey of India (P. N. Datta *coll.*).

Locality and horizon.—Shells of this species are abundant in a more or less fragmentary condition in beds of pinkish soapy clay from the neighbourhood of Namma in the Northern Shan States. They occur with *Taia naticoides* and *Paraprososthenia minuta.* The clay in which the species is found contains traces of the leaves of water-plants and the filaments of algae.

Relationships.—Oncomelania fragilis appears to be closely related to the living Chinese *O. longiscata* (Heude), but the shell is much smaller, the whorls more swollen and the penultimate whorl relatively smaller and more contracted.

ONCOMELANIA CONOIDALIS, sp. nov.

(Pl. 32, fig. 6.)

The shell is considerably shorter and broader than that of *O. fragilis* and of a more conoidal form, with the suture less impressed and the whorls less inflated. The longitudinal ribs are also more prominent. It differs from all described living forms in the shape of the shell, especially in its more uniformly broadly conoidal outline and less distinct whorls. The shell is about twice as long as broad, the length being about 5 mm. and the breadth 2·5 mm.

Type-specimen.—I have seen only one shell that I can assign definitely to this species. It is in the collection of the Geological Survey of India and is from the same set of specimens as *O. fragilis.*

Genus PARAPROSOSTHENIA, nov.

1883. *Diana* (in part) Neumayr, *N. Jahrb. Min.* Geol. Pal., II, p. 24.
1898. *Prososthenia* (in part), Neumayr, *Süssw. Moll.* in *Wiss. Ergebn. B. Széchenyi Reise in Ostasian* II, p. 653.

The shell is small and moderately thin, elongate, tapering and spire-shaped. It is ornamented with at least two spiral ridges bearing granular or nodular prominences on each whorl, except the apical and sub-apical whorls, which are smooth. The body-whorl is not inflated or greatly enlarged. The aperture is relatively short and broad and of ovoid form, pointed posteriorly and sometimes a little produced but not canaliculate. The columella is strongly arched but not twisted. Its callus takes the form of a delicate flattened ridge, which is continuous with the outer lip at both ends and extends over the narrowly rimate umbilicus. The outer lip is not thickened and is distinctly sinuate in lateral view.

Nothing is known of the operculum, radula or soft parts.

Type-species. *Paraprososthenia minuta,* sp. nov.

Distribution.—The type-species is from the Namma freshwater beds. A living form (*Diana* or *Prososthenia* (?) *gredleri,* Neumayr) is found in the lake Tali Fu or Erh Hai in Yunnan, south-western China.

The relationships of this genus are obscure, and its position in the family Hydrobiidae must be regarded as problematical until something is known of the operculum, radula and soft parts. Its identity with *Diana,* Clessin,[1] which was originally set up as a

[1] Clessin, *Malakoz. Blatt.* XXV, p. 127, pl. v, fig. 8 (1878).

subgenus of *Pyrgula* for a living Greek species (*Pyrgula* (*Diana*) *thiesseana*), if improbable is not impossible; but it differs in having a granular as distinct from a linear spiral sculpture, and according to von Martens [1] the name *Diana* was in any case preoccupied in fishes by Risso (1826).

The genus *Prososthenia*,[2] with which Neumayr in 1898 identified the living Yunnanese species provisionally, was described by him in 1869 to contain two Miocene Dalmatian species, *P. schwarzi* and *P. cincta*, both previously unknown. *P. schwarzi*, being described first, may be accepted as the type-species in the absence of any statement on the part of the author. Neumayr's generic description is as follows:—

> "Testa parva ovato-conica vel turrita, transverse plicata; ultimo anfractu coarctato, deflexo; apertura ovata, obliqua, integra; peristomate continuo, incrassato, duplicato; labro externo protracto."

Later (*op. cit.*, 1898) he included in the genus the species he had described in his paper of 1869 as *Pyrgula haueri*, while in 1883 he stated that this species was so near the Yunnanese form (*Paraprososthenia gredleri*) that they could hardly have been accepted as distinct species had they been found together. The structure of the mouth of the shell, however, in *P. gredleri* and in the fossil species here described does not seem to me to conform to Neumayr's description of *Prososthenia* or to his figures of the Dalmatian fossil shells.

Apart, therefore, from theoretical reasons, it seems to be justifiable to regard the two Asiatic species as representing a genus distinct from *Prososthenia*. This genus may be identical with Clessin's *Diana*, but differences exist between the shells, and in any case that name was preoccupied at the time it was published.

[1] Von Martens, *Zool. Record*, XV, p. 46 (1878). It is of some interest in this connection to note that a mollusc closely parallel to but distinct from the true *Pyrgula* occurs in Lake Tali-Fu as well as a typical *Paraprososthenia*. I have found numerous specimens of the former, of one of which I have examined the operculum and radula, in a collection made from that lake by Mr. J. Coggin Brown of the Geological Survey of India. This species represents a distinct new subgenus, which will be described shortly in the *Rec. Ind. Mus.* by Dr. Baini Prashad and myself. Certain features of its anatomy lead us to think that it is allied to the Pleuroceridæ rather than the Hydrobiidæ.

[2] Neumayr, *Jahrb. K. K. Geol. Reichsanst.*, XIX, p. 360, pl. xii, figs. 4, 5 (1869).

PARAPROSOSTHENIA MINUTA,. ps nov.

(Pl. 31, fig. 6; Pl. 32, figs. 1, 1a, 2.)

The shell is small and delicate, somewhat conoidally spire-shaped and a little more than three times as long as broad. It tapers gradually and evenly to the apex, which is minutely rounded. The whorls, which are slightly inflated, are 8 or 8½ in number, but the apical whorl or half whorl is usually obsolete in adult shells. The suture is linear, oblique and very little impressed except immediately above the body-whorl, and the whorls are neither shouldered nor angulate outside it. The body-whorl is longer, viewed dorsally, than the three whorls above it together. It is heart-shaped and bluntly pointed in front. The aperture is rather small and narrow and very oblique; it projects little beyond the body-whorl inwards. Its outline is pyriform and it is pointed and slightly produced posteriorly. The shell appears to have been narrowly rimate, with a broad but delicate callus produced over the umbilicus. The outer lip is not thickened and appears to have been evenly arched, but it is crushed and pressed inwards or outwards in the specimens examined. I have succeeded in extracting from the clay a very young shell with only 3½ whorls. This interesting specimen shows that the apical half whorl was slightly depressed and the first full whorl smooth and rounded, of course very minutely. A spiral band of minute granules makes its appearance on the dorsal aspect of the second full whorl and reaches its full development on the third. All the other whorls are similarly ornamented, but a second row of granules appears on the 4th or 5th; while the body-whorl bears three rows, which, at any rate on the ventral surface, are equidistant and equally well developed. The granules are rounded but very prominent. The base of the body-whorl is almost smooth, without band-like spiral ridges but with fine curved longitudinal striae.

Exact measurements cannot be given, but a large shell is about 6 mm. long and nearly 2 mm. broad.

Type-specimens in the collection of the Geological Survey of India (P. N. Datta *coll.*).

Locality and Horizon.—In pinkish clay from the Namma beds with the last two species. Present in considerable abundance.

Relationships.—This species is closely related to the living Chinese *Paraprososthenia gredleri* (Neumayr), but the shell is smaller and has a relatively smaller and more contracted mouth and is

distinguished by the three equal and equidistant rows of granules on the body-whorl and the broader callus.

Fam. Viviparidæ.

This family is represented in the Namma and Yenangyat beds by shells of at least three species, one of which still survives and is the type-species of the genus *Taia*. To the same genus, but in each case to a new subgenus, I assign the other two species.

Genus TAIA, Annandale.

1918. *Taia*, Annandale, *Rec. Ind. Mus.* XIV, pp. 123,160, pls. xv-xviii.

In the paper cited I have given a fairly full account of the genus as known to me before examining the collection of the Geological Survey of India. *Taia* may now be divided into four subgenera as follows :—

Taia, s.s.—Shell conical or conoidal, never very thick, with 7 or 8 whorls, with the base nearly vertical, with the columellar callus moderately developed, never visible to more than a slight extent in dorsal view; the sculpture consisting of irregular, sinuate, granular, tubercular or squamose spiral ridges and coarse longitudinal striae; spiral ridges occasionally obsolete.

Type-species.—Paludina naticoides, Theobald (recent and (?) Pleistocene; Upper Burma).

Temnotaia, nov.—Shell resembling that of *Taia* s.s., but thicker, with fewer whorls and ornamented with incised spiral lines instead of ridges.

TYPE-SPECIES.—*Taia incisa*, Annandale (subfossil; Upper Burma).

Crassitaia, nov.—Shell turbinate, broad in proportion to its length, very thick, with few whorls, with the base almost transverse and the columellar callus very strongly developed; the sculpture consisting of a comparatively small number of spiral ridges bearing blunt triangular projections.

TYPE-SPECIES.—*Taia infracrassata*, sp. nov. (? Pleistocene; Upper Burma).

Rivularioides, nov.—Shell conoidal, somewhat elongate, very thick, with few whorls, with the base almost vertical and the columellar callus very coarse and prominent; sculpture consisting (so far as it is preserved) of two spiral series of projections some of which are very long and have a spiny character.

TYPE-SPECIES.—*Taia spinifera*, sp. nov. (Tertiary; Upper Burma).

Subgenus TAIA (s. s.).

The subgenus can be divided into several groups which many malacologists would regard as species. From a strictly taxonomic point of view they would perhaps be justified in doing so, but I have pointed out elsewhere the inconvenience of complicating nomenclature by the introduction of subspecific names in groups of great complexity in which evolutionary principles must be considered, and after all taxonomy is not (or should not be) an end in itself, but a matter of convenience and common sense. Species are mere rungs in the ladder of evolution.

The following are the "groups" that I would recognize:—

1. Group of *Taia naticoides* (Theobald).

In this group the shell is distinctly conoidal and by no means elongate. The sculpture in the typical species is extraordinarily variable but in the others has become more or less standardized into a pattern of spiral ridges which are usually nodular and occasionally squamose. The group is or was paludine and fluviatile rather than lacustrine.

The species are *Taia naticoides* (Theobald), *Taia theobaldi* (Kobelt), *Taia intermedia*, Annandale and *Taia obesa*, Annandale.

2. Group of *Taia shanensis* (Kobelt).

This group consists of a single species (*Taia shanensis*), the shell-characters of which are intermediate between those of the preceding and of the next two groups. The shell is conoidal but slightly elongate and is ornamented with nodular ridges one of which bears squamose projections on the body-whorl.

Taia shanensis lives at the edge of the Inle Lake in conditions in which peat is produced.

3. Group of *Taia lacustris*.

The species of this group have elongate conoidal shells remarkable for the obliquity of the body-whorl. The sculpture consists

of well-developed undulated or nodular spiral ridges, which sometimes become squamose. The group, which is apparently extinct, was lacustrine in habits.

The species are *T. lacustris* and *T. cylindrica.*

4. Group of *Taia elitoralis.*

This group, which contains the largest species of the genus, is characterized by the conical, sharply pointed and regularly tapering shell and by the rather coarse and irregular but prominent spiral sculpture. One living species is found at the edge of the peaty area (Marginal Zone) of the Inle Lake and of clear water (Central Region). The others were or are probably similar in habits.

The species are *T. elitoralis*, *T. noetlingi*, *T. analoga* and *T. conica.*

5. Group of *Taia intha.*

The single species of this group is separated from the preceding one by the extreme delicacy and regularity of its sculpture. It lives in the still water of the Central Region of the Inle Lake.

TAIA NATICOIDES Theobald.

(Pl. 33, figs. 1, 2.)

1913 *Vivipara* sp., Tipper in La Touche, *Mem. Geol. Surv. Ind.*, XXXIX, p. 316.

1918. *Taia naticoides*, Annandale, *op. cit.*, pp. 126, 162, pl. xv, figs. 16, 17; pl. xvi, figs. 3—6, pl. xviii, figs. 1—3.

In the softer clay from the Namma beds there are two shells (Pl. 33, figs. 1, 2) which I cannot distinguish from this species. Neither is in good condition, but the sculpture of one is fairly well preserved and the mouth of both is nearly complete. Both belong to the heavily sculptured type to which Theobald gave the name var. *carinata.*

It is clear that in dealing with fossils of this kind one cannot apply the theory of specific determination enunciated above with the same vigour that can be adopted with abundant well preserved material. The shells are more or less crushed and their precise outlines cannot be traced. They may belong to a local race analogous to *T. intermedia*, but even so there can be no doubt of their identity in a wide sense with *T. naticoides.* It is most interesting to find that this extraordinarily variable and plastic

species is a survivor from Pleistocene times, for either it or the closely allied fluvitile *T. theobaldi* appears to have been the ancestor of all the *Taiæ* recent or extinct.

Subgenus CRASSITAIA, nov.

TAIA (CRASSITAIA) INFRACRASSATA, sp. nov.

(Pl. 31, fig. 11; Pl. 33, figs. 3-6.)

1913. *Melanopsis* sp., Tipper in La Touche, *Mem. Geol. Surv. Ind.*, XXXIX, p. 316.

The shell is thick, trochiform, broad in comparison to its height so far as the body-whorl is concerned but with the spire much narrower than that whorl. The apex is bluntly pointed. There are 5½ whorls, but the terminal half-whorl can hardly be distinguished in the adult shell. The embryonic shell consists of four and a half whorls. The apical half whorl is minutely depressed. Thence for the next two whorls the suture is hardly impressed but very oblique, so that the whorls increase rapidly in size. They are almost smooth and neither swollen nor shouldered. The third full whorl is transverse and less oblique than the second. It is broadly shouldered above and edged externally in its younger part by a broad irregular transverse ridge, which gradually assumes a nodular character and becomes separated from the rest of the whorl by a deep shallow transverse depression. The suture between this whorl and the next is linear and almost transverse. The fourth complete whorl bears two very distinct coarse spiral ridges ornamented with numerous projections that have the form of equilateral triangles slightly blunted at the apex and with the base attached to the shell. These ridges are almost equidistant from one another and from the upper suture. Between the upper ridge and the suture the surface of the shell slopes outwards slightly and there is no trace of a shoulder or angle. The fifth complete whorl or body-whorl is separated from the spire by a broad flattened area between its periphery and the upper suture, which is again linear and nearly transverse. This whorl is much broader than deep and almost band-like in form. It is ornamented with at least three ridges of a similar character to those on the fourth whorl, but the projections upon them sometimes show a

tendency to assume a longitudinal rib-like shape and at any rate on the median ridge are slightly concave on the side directed towards the ventral surface of the shell and thus have a somewhat scale-like character. The columellar callus (which is extremely coarse, distinctly plicated transversely and almost transverse in position) occupies the whole of the external surface of the base of the shell as a convex lunate plate. The aperture is relatively small and narrow, oblique, sub-triangular and bluntly pointed posteriorly. The outer lip does not appear to have been thickened, but is incomplete in the specimens examined.

Type-series in the collection of the Geological Survey of India (T. D. La Touche *coll.*).

The length of the shell is about 20 mm., the greatest breadth 16 mm., the length of the mouth 10 mm. and the breadth 7 mm.

Locality and Horizon.—The specimens on which this description is based are from freshwater beds in the immediate neighbourhood of Namma, in the Northern Shan States, and were collected by Mr. T. D. La Touche, who believes the beds to be probably Pleistocene. The shells (most of which are poorly preserved, though some of them contain the remains of embryos in a very fair state) are in a hard grey clay of even texture and minute structure and having the appearance of a lacustrine deposit.

Relationships.—The specimens are labelled "Paludomus, *nov.* sp." and "*Pyrgulifera infracrassata, nov. sp.*" The resemblance to the genus *Paludomus* seems to me very small and that to *Pyrgulifera*, which is regarded by Fischer as also belonging to the family Melaniidae, quite superficial. Tipper (*op. cit.*), in referring the species provisionally to *Melanopsis* of the same family, points out the essential difference in the structure of the columellar callus.

The shells are practically proved to be those of either Viviparidae or Melaniidae by the fact that many of them contain embryos, and fortunately the embryonic shells are very much better preserved than those of their parents. The general resemblance of the species to the genus *Taia* struck me immediately on seeing them, particularly on account of the peculiar structure of the columellar callus, which has no parallel in the Melaniidae. The embryonic shell is very like that of the living *Taia intha* [1] but the whorls are more transverse and the apical two and a half smoother.

[1] See Annandale, *Rec. Ind. Mus.*, XIV, p. 136, pl. xviii, fig. 3 (1918).

From the embryonic shell of *Margarya melanoides* [1] that of *Taia infracrassata* differs chiefly in its more exserted apex and less impressed suture. It is much broader than that of any Melaniid with which I am acquainted. The body-whorl of the adult shell, which is totally different from that of *Margarya*, differs from that of any species of *Taia* yet described in that it is flattened below so as to lie almost in a transverse plane. The callus is also still more strongly developed and the whole shell much thicker, resembling that of *Margarya* in the latter respect but having the thickness still more marked.

On these grounds I think that we are fully justified in regarding this new fossil species as being closely related to the species of *Taia* that live or lived in the Southern Shan States. Some of these species may be Pleistocene, but it is probable that the Namma form is older than any of them. The question of age, however, as I have pointed out above, is of no great importance in considering the relationships of species included in genera so plastic as *Taia*. *Taia infracrassata* has developed certain peculiarities which in my opinion render it worthy of subgeneric distinction, and there can be little doubt that these peculiarities were associated with isolation from its congeners; but its specialisation is not very much more extreme, though of quite a different nature, than that of living *Taia intha*.

Subgenus RIVULARIOIDES nov.

TAIA (RIVULARIOIDES) SPINIFERA, sp. nov.

(Pl. 33, figs. 7-12.)

The shells of this species are very imperfectly preserved and all the finer sculpture on the surface has disappeared, but fortunately large number of specimens are available.

The shape differs considerably in shells of full size from those half grown. In the latter it is somewhat globose, though very asymetrical, while in the former it is elongate-conoidal. In the young shell the base of the body-whorl is also less vertical. There are only 3½ or 4 whorls. The apex is depressed and the spire

[1] See Kobelt in Martini and Chemnitz's *Conch. Cab., Paludina (ed.* Kobelt), p. 193, pl. xxxvii, figs. 7—9 (1909); also Heude, *Moll. d'Eau Douce, Mém. Hist. Nat. Emp. Chinois,* I, pl. xliii, figs. lb, c, d (1890).

commences as a blunt rounded band, the tip of which does not quite reach the inner margin of the first complete whorl. This whorl also is band-like, somewhat convex and apparently smooth. The second complete whorl is again band-like but more than twice as broad as the first. It is angulate above and probably bore a distinct carina round its periphery. The third complete whorl is broader than deep, but very oblique. It is much deeper than the spire. The suture is deeply impressed but narrow, almost transverse on the spire but oblique above the body-whorl. The mouth is long, oblique and rather narrowly ovoid, pointed but not retroverted posteriorly and evenly rounded anteriorly. The columella is arched. The columellar callus is very coarse and prominent and extends inwards over a large part of the base of the body-whorl. The only sculpture that remains definite is a pair of spiral series of projections on the body-whorl. These projections seem to vary considerably in character but are evidently worn in most of the specimens examined. In some shells they seem to have been no more than blunt conical tubercles, while in others they have the form of coarse spines nearly half as long as the diameter of the shell, blunt at the tip and often concave or at any rate canaliculate on the side directed towards the mouth. Their tips appear to have been truncated and they project outwards and a little upwards. The upper series runs immediately outside the suture and seems to have consisted of three or four projections. The projections increased in size in the direction of the spiral, the uppermost never having a spiny character, while the lowest two were better developed than the others. The lower series also consisted of about four projections, which were shorter and more conical than those of the upper series. The largest were the two projections nearest the outer lip. This series was situated nearly at the middle of the whorl.

The approximate length of a large shell is 24 mm. and the greatest breadth (without the projections) 13 mm., the length of the mouth about 12·5 mm. and the breadth about 8·5 mm. The corresponding measurements of a young shell are 13, 11, 8 and 6 mm.

Type-series in the collection of the Geological Survey of India (Sethu Rama Rau *coll.*).

Locality and Horizon.—The specimens were collected at Yenangyat near the oil-fields of Upper Burma by Mr. Sethu Rama Rau.

They occur in great abundance in a hard ferruginous conglomerate of Tertiary age.

Relationships.—The species is tereinsting as providing a link between *Taia* and *Rivularia,* the only genera of Viviparidae with the peculiar columellar callus so characteristic of both. Heude [1] describes *Rivularia* as follows :—

"Testa quam crassa et solida ; anfractu ultimo rotundato, vel carinato, fere concham integram efformante ; peristomatis margine columellari plicis confertis multiplicato, dextro acuto. Animale paludinis simili, operculo elliptico, parvo, tenui, nucleo laterali-mediastino."

None of the species have spiral series of separate projections but in *R. auricula* [2] (von Martens) the body-whorl is ornamented with a pair of irregular and extremely variable spiral ridges in much the same position as the projections on the shell of *T. spinifera.* The resemblance between the genera lies in the shape and thickness of the shell and in the elongation of its mouth. In *T. spinifera,* however, these characters are less strongly developed than in the true *Rivularia.* I am inclined to think that the Yenangyat species is related to the ancestral form of *Rivularia* and indicates a common origin for the two genera.

EXPLANATION OF PLATES.

PLATE 31.

[*The actual length of each shell is indicated by a vertical line.*]

CONVERGENCE IN LACUSTRINE MOLLUSCS.

Convergent Group of Prososthenia—Oncomelania.

FIG. 1.—*Prososthenia schwarzi,* Neumayr, the type-species of *Prososthenia* from Miocene beds in Dalmatia. After Neumayr, *Jahr. K. K. Geol. Reichsanst.* XIX, pl. xii (1869).

FIG. 2.—Restored figure of *Oncomelania fragilis,* sp. nov, from (?) Pleistocene beds in the Northern Shan States.

FIG. 3—*Oncomelania longiscata,* Heude, from Tong-Ting Lake in Central China (living) After Heude, *Mém. Hist. Nat. Emp. Chinois* I, pl. xxxiii.

[1] Heude, *Moll. d'Eau Douce, Mém. Hist. Nat. Emp. Chinois,* I, p. 179 (1890).

[2] For figures of *Rivularia* see Kobelt, *Paludina* in Martini & Chemnitz's *Conch. Cab.* (*ed.* Kobelt), pls. xxv, xxvi (1909).

Convergent Group of (?) Prososthenia—Paraprososthenia.

FIG. 4.—*Pyrgula* (?) or *Prososthenia* (?) *haueri*, Neumayr, from the same beds as *Prososthenia schwarzi*. After Neumayr, *op. cit.*, pl. xi.

FIG. 5.—*Pleurocera* (?) *radmanesti*, Fuchs, from Miocene beds in Croatia. After Fuchs, *Jahrb. K. K. Geol. Reichsanst.* XX, pl. vix (1870).

FIG. 6.—Restored figure of *Paraprososthenia minuta*, sp. nov., from (?) Pleistocene beds in the Northern Shan States.

FIG. 7.—*Paraprososthenia gredleri* (Neumayr), from Lake Tali Fu, Western China (living). After Neumayr, *Süssw. Moll.*, in *Wiss. Ergebn. Reise. G. Béla Széchenyi in Ostasien*, II, pl. iv (1880).

Convergent Group of Tylotoma (?)—Margarya—Taia.

FIG. 8.—*Vivipara* (? *Tylotoma*) *recurrens*, Penecke, from Miocene beds in Slavonia. After Penecke, *Beitr. Palaent. Osterreichungarns* IV, pl. ix (1886).

FIG. 9.—*Margarya melanoides* var. *carinata* (*Neumayr*) from Lake Tali Fu, western China (living).

FIG. 10.—*Taia intermedia*, Annandale, from superficial peaty beds in the He-Ho basin, Southern Shan States.

FIG. 11—Restored figures of *Taia* (*Crassitaia*) *infracrassata*, sp. nov., from (?) Pleistocene beds in the Northern Shan States.

PLATE 32.

FOSSIL HYDROBIIDAE FROM THE NAMMA FRESH WATER BEDS, NORTHERN SHAN STATES.

Paraprososthenia minuta, gen. et sp. nov.

FIG. 1.—Type-specimen (× 7) in fairly soft pinkish clay.

FIG. 1*a*.—Body-whorl of same specimen further enlarged.

FIG. 2.—A larger specimen (× 7) from the same piece of clay seen in dorsal view.

FIGS. 3, 4.—Young shell from same deposit. Highly magnified: actual length 1 mm.

Oncomelania fragilis, sp. nov.

FIG. 5.—Type-specimen (× 7) from same deposit.

FIG. 5*a*.—Body-whorl of same specimen further enlarged.

Oncomelania conoidalis, sp. nov.

FIG. 6.—Type-specimen (× 7) from same deposit.

Oncomelania sp.

FIG. 7.—Imperfectly preserved specimen from same deposit.

FIG. 7*a*.—Body-whorl of same specimen further enlarged.

PLATE 33.

FOSSIL VIVIPARIDÆ FROM THE NAMMA BEDS, NORTHERN SHAN STATES AND THE YENANGYAT BEDS, PAKOKKU DISTRICT, UPPER BURMA.

Taia naticoides Theobald.

FIGS. 1, 2.—Shells in fairly soft pinkish clay from the Namma beds (nat. size).

Taia (Crassitaia) infracrassata, sp. nov.

FIG. 3.—A piece of hard grey clay from the same beds containing shells of type-series (nat. size). *a*, Shell as seen from below, showing callus. *b*, Shells seen in dorsal view.

FIGS. 4, 5.—Embryonic shell extracted from adult in similar clay from same deposit. Magnified: actual length 5 mm.

FIG. 6.—Callus of adult shell as seen from below (× 2).

Taia (Rivularioides) spinifera, sp. nov.

FIGS. 7—12.—Type-series of shells (× 2) from hard ferruginous conglomerate of Yenangyat beds.

THE GALENA DEPOSITS OF NORTH-EASTERN PUTAO. BY MURRAY STUART, D.SC., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 34 to 38).

INTRODUCTION.

THE galena deposits of North-eastern Putao occur in the Nam Tamai, Nam Tisang, and Upper Nam Kiu valleys in the extreme north-east of Burma, bordering on the China-Tibet frontier. The area is that lying between longitudes 97° 30′, and 98°, and latitude 27° 30′, and 28°. The Nam Tamai and Nam Tisang valleys are connected with Fort Hertz[1], the headquarters of the district, by a mule track, the Nam Tisang valley being five days march from Fort Hertz, and the Nam Tamai valley ten. Fort Hertz is connected with Myitkyina by a good mule road, which is 220½ miles long and is divided into nineteen stages with a rest-house at each stage. The Upper Nam Kiu valley has no mule track, and most of the way one has to climb along the bed of the river, there being no other path. The district is extremely mountainous, and covered with dense forest everywhere, and except on the few mule tracks of the district, it is necessary to cut one's way through the dense undergrowth. This makes geological surveying exceedingly slow, and the only possible course is to make a number of traverses across the country wherever it offers facilities for a path being cut, and to leave unsurveyed the intervening country, which is frequently inaccessible and always obscured by dense vegetation. Rice can be obtained on the Putao plain, but all other food and supplies necessary for a survey party must be brought from Myitkyina on mules. The Putao plain is about 1,100 feet above sea level, the Nam Tisang valley about 1,500, and the Nam Tamai valley about 3,500 feet.

[1] Fort Hertz is situated just to the south of the village of Putao.]

The Nam Tamai valley is sparingly strewn with isolated collections of lead "slag," practically all located along the path that winds along the valley, and along which all the habitations in the valley are situated. None of these collections of slag is of any size and no individual heap that I saw would provide enough slag to fill a wheelbarrow. The total amount of slag seen by me during my investigations was probably less than a ton. This so-called "slag" consists of partially burnt galena containing fragments of charcoal, and is mixed with broken slabs of litharge. The latter is sought by the Nungs who at present inhabit the valley, and is reduced by them to lead, which they use for weighting their fishing nets and also to trade with the neighbouring tribes who require lead for the manufacture of bullets.

There is a report current among the tribes of the north-eastern frontier that many years ago silver was obtained from the Nam Tamai valley and that extensive mines existed there.

In the Nam Tisang valley there is one locality which was worked for a few months by some Chinese many years ago. They extracted about half a ton of low-grade ore but soon, owing to sickness and the unhealthiness of the locality, they left everything, even the extracted ore, behind them, and they have never returned. The occurrence in the Nam Kiu valley has been known to the Nungs for years, but has never been considered worthy of attention by them.

The topographical map used by me was only a provisional one and suffers from occasional inaccuracies. Geological boundaries must consequently be regarded as merely approximate.

HISTORY OF THE AREA.

The Putao district until a few years ago consisted of unadministered territory, and was only taken under administration after 1912. South of the Putao plain—also known as Hkampti Long—the district is peopled by Kachins. On the plain is an isolated colony of Shans, and to the north-east the country stretching to the Tibetan and Chinese frontiers is populated by Nungs. South of the Nung territory is the area occupied by Lissus, but all that I am concerned with for the purposes of this report is the area occupied by the Shans and the Nungs.

The Shans, although similar in many ways to the Shans of Burma, show evidence of having been an isolated colony for a considerable time, and their customs and language show distinct differences from those of the Shans of the Shan States. Thus the Sawbwas of the Putao plain are not analogous to the Sawbwas of the Shan States; they keep up no regal state and live side by side with the villagers under exactly the same conditions and in exactly similar houses; they keep no retinue and are paid no particular respect. The Shan population is now very small, owing to inter-village warfare and to the fact that most of the vanquished went across the border into Assam. Formerly, if one may judge by the limits of the old cultivation, they must have formed a flourishing colony. Until the area was brought under administration the Nungs as a whole were considered the slaves of the Shans, each Sawbwa having certain tribes of Nungs who were considered specifically his own (the Nungs are still known as the Kanungs—the word *Ka*, meaning *slave*, being prefixed to the name of the tribe). About fifty years ago, according to tradition, the Shans used to compel the Nungs who inhabited the Nam Tamai valley to extract silver for them. Thus rumours of the existence of silver mines in the Nam Tamai are said to have reached the Burmese to the south of the district, and the Shans, fearing invasion, ordered the silver mines to be closed, and moved all the Nungs from the Nam Tamai valley into the hills on the south-west of the Putao plain. Such is the traditional story. It is true that galena was worked to a very small extent in the Nam Tamai, but the Nungs at present inhabiting that valley have all come there within the last fifty years and, beyond the tradition that silver mines used to exist somewhere, know nothing of the valley, or of old mines. The only Nungs who know anything about the old mines are old men who live on the south-west of the Putao plain and they only know that mines used to be worked in the Nam Tamai valley when they were children, but having never returned to this valley they know nothing of their situation.

The Shans know nothing beyond the fact that silver used to be obtained there. No Shan will go to the Nam Tamai valley, which is regarded as too cold, too inhospitable, and too difficult of access, and no assistance or information of any value can be obtained from them. Consequently search had to be made for traces of old mines in the places where tradition located them.

In some cases the search was successful, and in others not. I was fortunate in obtaining the services, as interpreter, of an old Shan who had formerly collected revenue from the Nungs of the Nam Tamai valley for the Shan Sawbwas of the Putao plain. In consequence I had the services of the man who had, at the time, more influence with the Nungs than any one else in the district, and so was able to obtain from them all the assistance and information it was in their power to give. The traditional story of the mines appears to be fairly correct, and errs only in the exaggerated reports of the amount of silver formerly obtained. On that point the evidence of the slag in the valley is conclusive; there are no accumulations comparable with those of Bawdwin, in the Northern Shan States, the slag in the Nam Tamai valley being only mere sprinklings, and, as I have already stated, I did not see much more than a ton throughout the valley. Nor are there in the Nam Tamai any traces of regular furnaces where smelting was carried on, but the Nungs apparently collected galena and smelted it in small quantities beside their houses. Consequently accumulations of slag are always insignificant in size. The Nungs are an exceedingly primitive tribe, and their state of civilisation and development is not such as would lead one to expect them to have worked on any but the crudest lines. They apparently smelted the galena in diminutive furnaces comparable in size to those in which at present they work the slags, subsequently oxidizing the lead to litharge beneath which the silver remained as a "button." The slabs of litharge so obtained were thrown away with the slag. They apparently used no fluxes and merely reduced the galena with charcoal. They possess no iron implements or tools other than their *dahs*, and for excavating, or mining, they use merely sharpened wooden stakes and stone hammers (made by tying a cane handle on to a suitably shaped river pebble). This being so, extensive mining was out of the question, and their probable mode of procedure was to collect galena in small pieces wherever they could find it and when they had sufficient collected, to smelt it and burn off the lead. The question of working at a profit did not arise. They were not paid for their labour. The provision of silver was one of their chief obligations as slaves.

It is necessary to realize this in order to understand that the working of galena in the Nam Tamai was not necessarily a profitable commercial proposition.

GENERAL GEOLOGY.

Topography.

The Putao district is extremely mountainous, the mountain slopes are frequently precipitous and mountains and valleys alike are covered with the densest forest. So dense is it that the trees grow straight up eighty and one hundred feet before branches appear, their base being surrounded by practically impenetrable undergrowth. One of the reasons for this profuse vegetation is that the rains commence early in February and continue until October, while during the remaining months between nightfall and ten or eleven o'clock in the morning, everything is shrouded in dense mist, and moisture condenses on, and drips from, every leaf and every twig.

In the centre of the district is the Putao plain, an isolated plain surrounded everywhere by mountains. The origin of the plain is not clear. Nowhere else between its source and its confluence with the Nmai Hka—25 miles above Myitkyina—does the Nam Kiu show any sign of having changed its bed, while on the Putao plain it has obviously swung from one side to the other, and remnants of old river terraces exist—Fort Hertz being built on one. The plain is approximately twenty-six miles long, and in its widest part eight miles broad. The hills and mountains on the south seldom exceed 4,000 feet in height, the height of the majority being less than 3,000. To the north and north-east of the Putao plain, however, the mountain ranges rise to 6,000 or 7,000 feet where they fringe the plain, and to as much as 16,000 and even 20,000 along the Tibetan border. The mule track from Fort Hertz to the Nam Tamai valley is thus impassable for elephants while even mules not infrequently succumb on the last pass into the Nam Tamai; individual loads therefore are limited to a weight of 120 lbs. and this practically precludes the transport of machinery to the Nam Tamai valley. North-east of the Putao plain most of the mountain ranges are either composed of granite or have granitic cores. This granite is exceedingly soft and decomposed at the surface, and landslips are of very frequent occurrence, one of the characteristic features of the granite mountain-slopes being great rock avalanche tracks scoured clean of all vegetation where slips of the decomposed granite have occurred. On the western side of the Nam Tamai valley there occurs a series of highly siliceous

limestone, forming steep jagged peaks. It is in this series that the occurrences of galena that I found in the Nam Tamai valley all occur.

Geology of the Area.

The rocks of the area consist of—

(1) Tertiary sandstones and clays and occasional conglomerates :

(2) A metamorphic series of schists, slates, phyllites, and occasional graphite schists.

(A) Intrusive igneous rocks : granite, syenite, andesite, peridotite.

The Tertiary sandstones and clays.—These consist of yellowish and whitish sandstones often containing kaolin, with occasional leaf impressions ; they are frequently false-bedded. The clays are rare, but where seen consist of thin bands of blue clay in the sandstone. Leaf impressions are more common in the clays and certain horizons are crowded with them. The conglomerates occur interbedded with the sandstones and sometimes apparently overlying them, the commonest pebbles being syenite from the neighbouring intrusions into the metamorphic series of the area.

The Tertiary series is seen on the Myitkyina-Fort Hertz road between Paukaung, 27 miles north of the confluence of the Nmai Hka and the Mali Hka, and Fort Hertz ; in fact the road wanders on and off it for more than 130 miles, and follows roughly along its boundary with the underlying schists. The Tertiary beds seem to dip to the west and to form a long syncline between the road and the Kumen range.

The metamorphic series.—The metamorphic series with its included igneous intrusions seems to cover the rest of the district. The age of the rocks is extremely difficult, if not impossible, to fix. The series in places seems to exhibit certain Dharwar-like characteristics. For instance near the confluence of the Mali Hka and the Nmai Hka, nearly 160 miles south of the area shown on the map accompanying this report (Pl. 38), the schists are veined with red jasper ; along the road, north of Nsop, graphite-schists occur, and limestone is exceedingly scarce in the area, although calc-gneisses occur in the neighbourhood of Nsop, 18 miles north of the confluence of the Mali Hka and the Nmai Hka. The above

resemblance, however, may have no significance. It is obviously impossible to attempt to correlate metamorphic rocks over vast distances by the degree of metamorphism exhibited, and I have no evidence as to the true position of these schists and slates in the Geological Record.

The intrusive igneous rocks.—These include various granites, syenites, diorites, andesites, pyroxenite and peridotites. Whether there is any genetic relationship between the different varieties or not, I have no evidence to show. The main igneous intrusive rock seen along the road between Myitkyina and Fort Hertz is a biotite-syenite. It is first met with near the Hpungin Hka bungalow, 43 miles south of the area shown on the map (Pl. 38), and from there northwards, is met with periodically along the road till it crosses the Nam Yak. It is from this syenite that most of the pebbles in the Tertiary conglomerates are derived, and from the appearance of the kaolin-bearing Tertiary grits and sandstones, they also are composed mostly of material derived from the syenites. The biotite-syenite is gneissose wherever I encountered it along the road. Just below Nsop, along the road, one encounters a serpentinous and chloritic rock which has the appearance of being an altered peridotite, and a few miles off the ford across the Nam Yak (mile 190 approximately) there is a small hill which, where the road crosses it, consists of a pyroxenite composed almost entirely of hypersthene.

East and north-east of the Putao plain is a mass of intrusive biotite-granite with white felspars. For some distance outwards from the plain, this granite shows foliation and in places passes into a kind of quartzose gneiss without mica. Outwards from the plain, however, the foliation disappears and in the Nam Ti valley the granite becomes porphyritic with large crystals of felspar. This granite forms the mountain ranges on either side of the Nam Tisang valley and nearly all the mountainous country at the head of the Nam Tisang and Nam Kiu, and to the north-east of the Putao plain.

On the divide between the Nam Hat and Nam Tamai one crosses a ridge of hornblende-diorite, andesite and biotite-granite; the granite differs distinctly in appearance from the Putao granite; it is less readily weathered, and forms a fairly high mountain ridge (generally about 7,000' high). This ridge of igneous rock is seen again at the junction of the Nam Tamai with the Taron. A branch

of it runs down between the Nmai Hka and the Nam Hat, and forms the divide between the two, at least in their upper reaches.

The centre of the Nam Tamai valley is occupied by another variety of white granite, containing much more free quartz than the varieties above-mentioned and generally little or no biotite. It occupies the bed of the river and joint planes in it have a general westerly dip. In other words it shows an arrangement into thick bands which have an apparent dip towards W. N. W. The outcrop of the junction between the granite and the calcareous rocks also behaves as if the surface of the granite dipped to W. N. W. This effect is well seen under Salamkong and is shown on Pl. 35. In this place vertical dykes of hornblende-andesite are seen traversing the granite.

On the eastern side it passes into the adjoining schists, giving a rock consisting of calcareous and siliceous material with *lit par lit* injections of granite Pl. 37, fig. 2. This hybrid rock forms the eastern side of the valley, and extends up to the top of the divide.

In addition to the dykes of hornblende-andesite which occur in the granite under Salamkong, the same rock and diorite also occur near the crest of the Nam Tisang-Nam Kiu divide near Lang Razi. Their relationships are generally obscure but the presence, on one side of a granite boulder, of a thin coating of andesite showing a fine texture and indications of being a thin rapidly chilled veinlet, suggests that the andesite, and therefore probably the diorite also, is a subsequent intrusion into the granite. Although all the granites contain biotite and white felspar there is a distinct difference between them in the field, and, for simplicity, I have separated them into :—

The Putao granite,

The Taron granite,

The Nam Tamai granite.

It is possible that they and also the Hpungin Hka syenite, are genetically related, but the geological investigation is not sufficiently detailed or complete to determine this and they have consequently been shown on the map as different rocks.

The Geology of the Nam Tamai Valley.—I have already pointed out that the centre of the valley is occupied by the Nam Tama granite. To the west it is in contact with highly siliceous, calcare

ous rocks, white in colour, with slaty cleavage planes almost vertical, and weathering into extremely steep jagged peaks. The divide between the siliceous limestone country and the Nam Puti valley is composed of a hard quartzite. North of the Nam Puti valley the top of the western range bounding the Nam Tamai valley seems to consist of Putao granite, which from there seems to stretch across the Nam Kiu to the north of the Putao plain.

All the galena veins that I saw in the valley occur in the siliceous limestone, but it is possible that they may occur along a line of fracture and may not be genetically connected with this rock. In the Tari Wang there is an immense amount of a coarse siliceous limestone breccia which may well be a fault breccia and may indicate a fault running more or less along the line of the Tari Wang; this may account for the rather irregular shape of the range just about the head of the Tari Wang.

North of this tributary, siliceous rocks intervene between the limestone and the Nam Tamai granite, and it rather appears as if the strike of the calcareous rocks became more westerly to the north of the Tari Wang. It was impossible to get definite evidence on the point; the side valleys are uninhabited and almost inaccessible. When one succeeds in penetrating them, the forest is so thick that very little can be seen. The only path is frequently carried up perpendicular rock faces on a light bamboo pole with notches cut in one side, and at times even up the vertical and smooth face of a waterfall, through the falling water.

East of the Nam Tamai the country is occupied by the hybrid granite and calcareous rock already described. This hybrid rock frequently contains flakes of graphite, both in the *lit par lit* injections and also in the intervening calcareous sheets.

The Galena.—An old galena mine occurs in the northern side of the Pyit Wang. It is situated some 4 miles up the stream, above its junction with the Nam Tamai, and is high up on the left side of the gorge, about 1,000 feet above stream level, in the highly siliceous limestones already mentioned. The climb to it from the stream is extremely steep.

There are no inhabitants of the valley, and a road had to be cut through the dense undergrowth. Starting from Salamkong, on the Nam Tamai, it took six hours to reach the mine although the road had been cut previously.

The mine itself is an old natural cavity—probably largely dissolved out by percolating water—carrying a vein of ferruginous material 10 inches wide. This was probably, originally, iron pyrites with sparsely disseminated veinlets of galena. I saw no vein of galena of greater thickness than ½ inch and that died out within a distance of six inches. In places the country rock contains galena and pyrites in minute particles scattered through it, but not in sufficient quantity to be of any economic value. The whole excavation is about 10 feet long by 10 feet deep by 4 feet wide at the broadest place; the ore-body appears to have been worked out. Plate 34 shows a photograph of it. The hammer indicates the small size of the "mine." There is a cavity a little below—really a continuation of the natural fissure—from which a certain amount of material also appears to have been taken. I tried without success to find traces of galena in this cavity. The bearing of Marit Wang Hpawng (by prismatic compass) from the mine is 142°.

Good crystalline galena from the veinlets assays:—
lead, 81 per cent. and silver, 38·75 ozs. per ton of ore.

Ore of lower grade assays:—
lead, 23·5 per cent. and silver 10·75 ozs. per ton of ore.

I do not consider the deposit of sufficient size to be of any economic value.

The Sheng Wang Mine.—Starting southwards from Paralangdam one crosses the Nam Tamai at its junction with the Sheng Wang and thence follows up the bed of the Sheng Wang to the foot of Klangtung Razi. From this point, at which I camped for the night, it is a stiff climb up the steep mountain side, to approximately the 8,000 feet level, to the mine.

The "mine" is in a vein of ferruginous material in siliceous limestone running approximately south 20° east, and cutting across a projecting spur of the hill. The vein had been completely worked out and no galena could be found *in situ*. From the evidence to be gleaned from fragments left behind by previous miners, the deposit seems to have been very similar to that at Pyit Wang but is even less valuable. It is a three hours' climb from the nearest water or habitable spot. There is no ledge near, where any habitation could be erected—in fact there was no ledge wide enough to enable me to take a photograph of the excavations; the cold was intense, and climbing dangerous without ropes.

The galena left behind by the Nungs who worked the deposit assayed :—

lead 61·73 per cent. and silver 39·5 ozs. per ton of ore.

I do not consider the deposit to be of any value. There is no indication of galena being present in quantity and even if there were, the situation of the deposit would debar any hope of profitable exploitation. Labour could not be housed at the mine.

Except at the above two places no galena was seen by me in the valley of the Nam Tamai or its tributaries. It is reported that it was once worked at Tayong Kang, the hill in the junction between the Nam Tamai and the Tari Wang, but no trace of the workings could now be discovered. It is also reported that it was once worked in the Daru Wang, but here again I could find no trace of any mine, and search parties sent out were equally unsuccessful.

Galena other than in the Nam Tamai Valley. Gum Ti.—Galena was once worked at the head waters of the Gum Ti, a western tributary of the Nam Tisang. It occurs as a vein six inches wide in siliceous, slightly calcareous, schistose rocks, in the southern bank of the Lun Shit Wang. It was worked many years ago by Chinese who had heard of the place and who came across from China to investigate it. They dug out the vein to a depth of two feet below water level, but sickness and fever compelled them to abandon this work and they left behind them all the material they had extracted. They have apparently never thought it worth while to return. The vein runs north and south, and due south across the Gum Ti is Noi Ngun which is sometimes said to mean " silver mountain ",[1] but there is no record of why the mountain received this name and the extension of the vein is extremely doubtful. The Gum Ti valley is uninhabited, and it took four men eight days to cut a path through the undergrowth from the Nam Tisang to the mine.

The ore assays :—

lead 50 per cent. and silver 49 ozs. per ton of ore.

I do not consider that the deposit is of any economic value.

The Nam Lang.—High up on the Nam Kiu-Nam Tisang divide, on the western slope of Lang Razi, is a small deposit of galena in

[1] It is doubtful whether "silver mountain" is the correct interpretation of the local name for the mountain; several Shans to whom I spoke about it assured me that it was not.

granite in the northern bank of the Nam Lang. It is well known to the Nungs and has been known for many years, but has never been thought worthy of attention by them. It is on the regular pass across the hills, but is two days' journey from the nearest village, and at an elevation of about 6,500 feet. The galena occurs merely as small ramifying veinlets, and nowhere did I see a vein of more than a few inches in thickness, that of most veins being only half an inch or less.

The galena assays :—

lead 69 per cent. and silver 49·75 ozs. per ton of ore.

The occurrence has no economic value.

It would appear therefore that Putao has no known galena deposit worth consideration.

Other Minerals. Gold.—Information was brought me that gold was being washed from the side of a mountain near the Pasang Wang, about half a mile down the Nmai Hka below the confluence of the Nam Tamai and the Taron (Pl. 36).

On investigation the workings proved to be mere alluvial scratchings in the river alluvium about high flood-level on the western bank of the Nmai Hka (Pl. 37, fig 1). The washing was being done by Lissus who had wandered up-stream from their own country, sampling the bank all the way. They had all left when I arrived, so I could get no information from them, but I understand that their takings are exceedingly small, and from panning results I am of opinion that the occurrence is of no value commercially. As there is no record of the occurrence of gold in the Nam Tamai, it would appear that this alluvial gold is brought here by the Taron from beyond the Chinese border.

In addition to the above, gold is reported to exist in the Akyaung valley between the Nmai Hka and the Chinese border, about latitude 27° or 27° 30′. According to the Deputy Commissioner of Putao, parties of Chinese come across the border from China each year into the Akyaung valley, and wash for gold. It is said that these Chinese divert mountain streams and wash down the soil on the mountain sides, obtaining gold nuggets and dust from it. There is, I think, little doubt that the rocks composing the mountains in the Akyaung valley are slates and schists similar to the Nsop schists described in the foregoing pages, so that the presence of gold dust and nuggets in the soil covering the mountain slopes, to the extent suggested by report, is unlikely.

The same report was current about the Pasang Wang gold washings described above, but, as I have already shown, this proved to be erroneous, the workings being really alluvial washings in the recent river alluvium. I mentioned this case to the Sub-Divisional Officer of Kanglu (in which sub-division the Akyaung valley is situated), and he told me that the Akyaung valley case is the same, namely, that the Chinese do not wash the sides of the mountains but the river alluvium along the banks of the river. Some rather fine nuggets were shown me by Mr. Hertz which were reported to come from the Akyaung valley—one was almost an ounce in weight—but it seems desirable, in view of the conflicting nature of the reports and the great distance of the Akyaung valley from Fort Hertz, that more definite information should be obtained locally before steps are taken to make a geological examination of the valley. It would be advisable to ascertain where and how the Chinese wash as well as the quantity of gold won by them annually. The gold found in the river alluvium comes, of course, from rocks within British territory, but it would be impossible to transport mining machinery there and consequently vein gold if it exists would have to be extraordinarily rich to make the proposition of mining it worth consideration. Alluvial gold is not likely to be a valuable commercial proposition in the Akyaung owing to the distance of the valley from all civilisation and food supplies, while the Lissus who inhabit it are a warlike and uncertain tribe, and even for ordinary touring a strong escort is necessary.

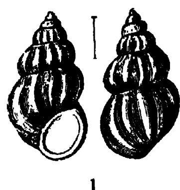
Iron.—The iron ore of Putao is of no commercial value, but its occurrence is peculiar and seems worth describing. It occurs as two huge isolated boulders of limonite in the upper reaches of the Hkalaw Wang, at the foot of the south-eastern slope of Kaungtang Hpong (situated at the head of the Daru Wang valley in the Nam Tamai-Nam Tisang divide). It was probably originally a replacement product filling a fracture and its interest lies in the fact that it is almost directly on the line of the two galena mines in the Nam Tamai valley; a line drawn through these places would pass through Tayong Kang where the reputed, but unfound, old silver mine is said to be situated and would also pass near Tasa Ku (on the Nam Tamai road on the east of the Nam Tisang valley) where according to a report current in the district, silver used also to be worked. All this may be mere coincidence, but the possibility of its indicating a line of fracture cannot be excluded.

It was hoped that platinum might be met with in the Putao rivers, but no indication of its presence was found.

Summary.—The amount of lead slag in Putao is insignificant, while the galena deposits visited are of on economic value; even were they rich and extensive, the difficulties of transport in the district are at present such as to preclude the possibility of profitable exploitation.

LIST OF PLATES.

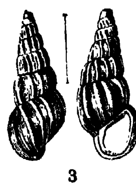
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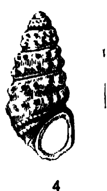
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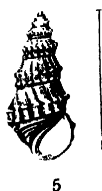
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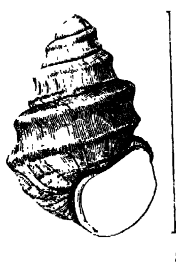
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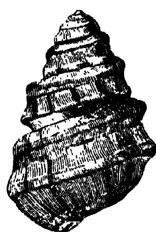


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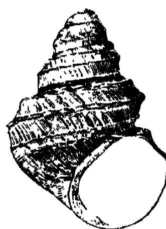


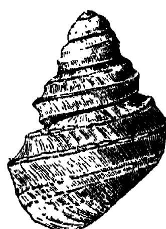
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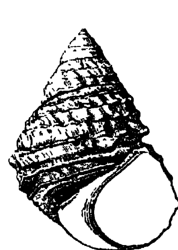


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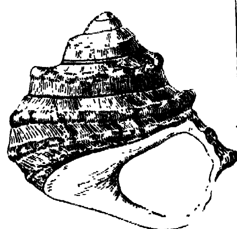


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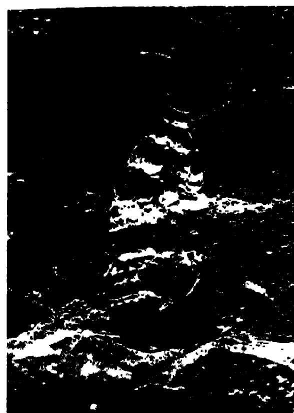




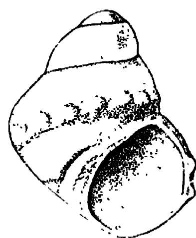
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G. S. I. Calcutta.

CONVERGENCE IN LACUSTRINE MOLLUSCS.



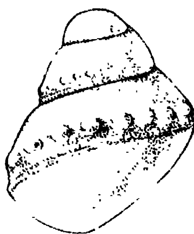
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BURMESE FOSSIL HYDROBIIDÆ.



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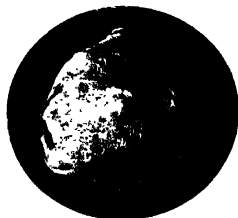
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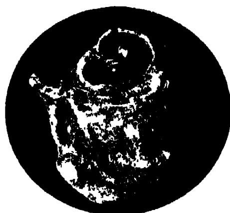
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Photo. G. S. I.

G. S. I. Calcutta.

BURMESE FOSSIL VIVIPARIDÆ.

Records, Vol L., Pl. 34.



Photograph by Murray Stuart. *G. S. I. Calcutta.*

THE PYIT WANG GALENA MINE. (The hammer handle is 18 inches long.)



Photograph by Murray Stuart. *G. S. I. Calcutta.*

GRANITE IN THE NAM TAMAI.



G. S. I Calcutta.

CONFLUENCE OF THE NAM TAMAI AND THE TARON.



FIG. 1. EXCAVATIONS FOR GOLD IN THE WESTERN BANK OF THE 'NMAI HKA.



Photos. by Murray Stuart. *G. S. I. Calcutta.*

FIG. 2. LIT-PAR-LIT INJECTION OF GRANITE INTO CALCAREOUS SCHIST.

FIG. 2. LIT-PAR-LIT INJECTION OF GRANITE INTO CALCAREOUS SCHIST.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA

Part 4] 1919 [December

ON PITCHBLENDE, MONAZITE AND OTHER MINERALS FROM PICHHLI, GAYA DISTRICT, BIHAR AND ORISSA. BY G. H. TIPPER, M.A., F.G.S., F.A.S.B., *Geological Survey of India.* (With Plates 39 to 42).

IN April 1917, the late Mr. H. E. Tiery, who had previously discovered pitchblende near the village of Pichhli, brought to the Geological Survey Office a number of specimens which he had found associated with this mineral. Among them was a reddish brown mineral identified as monazite. I visited the locality in May 1917. Owing to urgent work connected with the war the examination of the material then collected could not be carried out. The following description embodies the completed results.

SITUATION.

Pichhli (35° 26′ : 24° 34′ 18″) is a hamlet 3 miles north of Dilwa Railway Station and 7 miles south-west of Rajauli, in the Singar Zamindari, Gaya District, Bihar and Orissa Province. About ¼ mile east of the village is a line of small conical hills running from north-west to south-east. In the second of the small hills counting from the north-west the minerals about to be described occur.

GEOLOGY.

The small hills already referred to have been carved out of a mass of pegmatite intruded into garnetiferous mica schists. The pegmatite strikes N. N. W.—S. S. E. The form of the pegmatite

B

cannot be made out as it is largely obscured by a thick overburden of quartz and felspar rubble derived from the weathering of the finer grained portion of the pegmatite and partly from the quartz core. The texture of the pegmatite varies from a comparatively fine crystalline mixture of quartz, felspar and mica with black tourmaline intergrown with the quartz, to fairly large segregated masses of the main constituent minerals. It is in the latter that a small prospecting pit had been sunk for mica and from which the collection of minerals to be described was made. The felspar is microcline and in the larger masses is graphically intergrown with quartz. It is generally yellowish in colour but crystals were found pink and flesh red. The mica is distinctly greenish in colour and often badly cleaved. The quartz is dark, almost black, but transparent. The colour is completely destroyed at a bright red heat leaving the mineral clear and white. Pink garnets are not uncommon and occur flattened and platey in the small books of mica. The rarer accessory minerals, pitchblende, monazite and columbite occurred together in the small pit and in the coarser portion of the pegmatite.

Pitchblende.

In the felspar of the pegmatite and particularly in that near the masses of columbite and in one case intergrown with the latter mineral, occur a large number of nodules of a light yellow colour varying in size from a quarter of an inch to two inches or more in diameter. On breaking some of the larger nodules a black core of pitchblende is exposed. The smaller nodules are completely decomposed and no core now remains.

The black core is never quite unaltered. The mineral is usually dull and pierced by a network of cracks filled with a reddish translucent substance. The radiogram on Plate 41, fig. 5, obtained by exposing a plate direct to a smoothed piece of pitchblende shows this feature quite well. The black core shades off gradually into the yellow aureole of decomposition for which uranium ochre is a convenient term. The specific gravity of a piece of the black mineral is only 6·68.

The chemical changes involved in the formation of uranium ochre from pitchblende are shown in the following partial analyses. These analyses have no claim to great accuracy but they were done

under similar conditions and seem to represent fairly the changes involved.

	Pitchblende.	Uranium Ochre.
SiO_2	1·16	12·09
U_3O_8	66·24	34·74
Rare earths including Thorium	13·9	23·16
PbO	12·49	19·1

In addition both contain iron, manganese and barium. The ochre reacts strongly for phosphates. The changes are chiefly leaching out of the uranium which no doubt goes to form uranium bearing minerals of secondary origin, the phosphatisation of the ochre and probably also carbonatisation. It is interesting to note that there is evolution of large quantities of gas from both on solution in nitric acid.

Crystals in Uranium-Ochre.

The mode of occurrence of the uranium ochre as rounded nodules in the felspar is very suggestive of an isometric habit for the original mineral. Careful search with a little development brought to light five beautiful specimens of a crystallised variety. The faces are clean and well formed with sharp edges. Parallel growths are not uncommon. No complete crystal has been found but there is more than sufficient material to enable the forms to be determined as a combination of the cube (100) and the octahedron (111). The uranium ochre being rather soft and friable, the measurement of the angles without injuring the faces was a matter of some difficulty. This was solved by cutting an approximate angle as judged by eye in a piece of moderately stiff paper. This was then trimmed until it fitted when the angle was measured direct.

There can be no reasonable doubt that these crystals are pseudomorphs in uranium ochre after uraninite. The largest and most perfect of these crystals is shown on Plate 39, fig. 1. To the right of the large example is another smaller but similar.

Other Uranium-bearing Minerals.

Torbernite.

Torbernite is common and occurs encrusting mica, apatite and other minerals of the pegmatite, lining cavities and along cleavage cracks in the felspar.

The form is the usual thin, square table and the mineral is bright green in colour.

Autunite.

Autunite occurs as a lemon yellow-incrustation on some of the minerals. It is, however, much less common than torbernite and is not found crystalline. Both these minerals seem to be of secondary origin, the uranium being derived from the decomposition of the uraninite.

Comparison with Abraki Pahar.

The occurrence of pitchblende at Abraki Pahar, which lies about 5 miles east-south-east of Pichhli, was described by the late Mr. R. C. Burton and his description given in the Annual Report of Geological Survey of India for the year 1913 (*Rec., G. S. I.*, Vol. XLIV, p. 24). I also have had two opportunities of examining this locality and I merely wish to compare and contrast the occurrences.

The mode of occurrence of the pitchblende is similar in the two cases as nodules surrounded by an aureole of yellow uranium ochre but at Abraki Pahar the nodules are of much larger size and in addition are often found in masses of "triplite." As a consequence of the larger size the central uraninite is much less altered and the density is much higher. No crystals or pseudomorphs have yet been found at Abraki Pahar. As at Pichhli autunite and torbernite occur. Columbite is common at both places but whereas at Pichhli it is generally in well-formed crystals, at Abraki it is generally in flattened striated plates.

The "triplite" of Abraki is not by any means a simple mineral but is a complex mixture of at least four phosphates, the relationships of which have not been worked out. One is grey and resembles apatite, a second is dark green and transparent, a third is brown and may be true triplite, the fourth is a beautiful dark purple. They differ in physical and chemical properties. At Pichhli the phosphates found are apatite and monazite, often intergrown. At Abraki a common mineral is a dark brown, almost black zircon. It occurs in crystalline masses in the pegmatite and as isolated crystals in the felspar and occasionally in the quartz. The forms are *a* (100) and *p* (111). An interesting feature is the presence of well-marked and beautiful zoning (Plate 40, fig. 2). The dark colour of the mineral is destroyed by heat. No mineral of this type has yet been found at Pichhli. As at Pichhli the felspar is generally microcline and the quartz is dark coloured

Monazite.

This mineral occurs as isolated crystals and semi-crystalline masses in the felspar. Frequently it is intergrown with columbite and in one instance a small crystal of monazite is completely enclosed in the former mineral. It is also intergrown with mica. With apatite it forms an intimate mixture illustrated on Plate 41, fig. 1. In this many small crystals of monazite are seen enclosed in a matrix of light green apatite. The density of the mixture is 3·8 corresponding to 30 per cent. monazite. A single di-hexagonal crystal of apatite was found growing on a portion of a monazite crystal (Plate 41 fig. 4).

The size of the crystals varies but many are of exceptional size. A fragment of one weighs 500 grams and is some 8 cm. long, while the smallest is a little over 1 cm. in length. One of the semi-crystalline masses weighs over 1½ kilos.

The smaller crystals are sharper and better preserved than the larger, but all have suffered considerably from corrosion from some other mineral, mica, felspar, etc., with the effect that some of the faces are so badly scarred and distorted as to be useless for the purposes of measurement. Curved faces are common, particularly on the larger crystals. Parallel growths (Plate 41, fig. 2) and interpenetration groups (Plate 41, fig. 3) are frequent.

The crystals are prismatic and also flattened || to *a*. The following forms have been distinguished :—

a (100)	*n* (120)
b (010)	*e* (011)
m (110)	*u* (021)
w (101)	*r* (111)

The dominant faces in all the crystals are in order of importance *w*, *a*, and *m*. The face *r* is usually present and conspicuous; *u* and *e* are small; *b* is only developed sparingly on a portion of a large crystal. The tendency is for the right hand part of the crystals to be more fully developed than the remainder (see Plate 42, fig. 1). The illustrations of three good small crystals on Plate 39, figs. 2, 3, 4, give an excellent idea of the habit and external characters of the mineral.

The colour of the mineral is reddish-brown with a resinous lustre. The specific gravity is 5·2. Thin sections show that the mineral has undergone a considerable change from weathering and also that the colour is yellowish. The cleavages are those usual in monazite.

Absorption bands can be readily obtained with a direct vision spectroscope.

The thoria content is high, an average of three determinations giving 9·95 per cent. Th O_2. (As these determinations were done on a single fragment, they do not necessarily represent the average of the whole of the monazite found.) The thoria was precipitated by means of hydrogen peroxide.

Comparison with other monazite deposits in India.

As is well known, extensive deposits of monazite occur in the sands on the coast of the State of Travancore. It has also been found in the pegmatites in the State. The mineral as there found does not resemble that of Pichhli in its physical characters. Monazite occurring near Bangalore, Mysore State (5th milestone, Bangalore-Kakarihalli road) referred to in *Mineral Resources of Mysore*, p. 191, resembles the material from Pichhli very closely. It is similar in colour, density and external physical characters. It is, however, fresher and its thoria content is lower. The cleavages are more perfectly developed and it shows in a very striking manner multiple twinning, parallel to the face *b*, which in thin section under polarised light makes it an object of great beauty (Plate 40, fig. 1).

Columbite.

This mineral occurs as crystals of varying sizes arranged as fan-shaped aggregates in the felspar of the pegmatite, the terminations of the crystals being directed outwards. Its association with monazite and uranium ochre has already been noted. Practically every piece of columbite was crystalline, either complete in itself or broken from some other crystal. The size of the crystals varies from a small good crystal weighing only 5½ grams to one weighing over 6 kilos.

The crystals are well formed but only singly terminated. The faces are sometimes bright and clean but more often covered with a thin, brownish limonitic deposit or a yellowish crust reacting for uranium. Pitting and slight corrosion by quartz and felspar also occur. Groups of crystals in parallel growth (Plate 39, fig. 5) are very common. Sometimes the growths are not truly parallel, as in the specimen figured on Plate 39, fig. 7, where the smaller growths are distinctly curved.

The crystals are prismatic and elongated vertically and if doubly terminated would resemble a double-edged axe. The following forms have been identified :—

a (100)	*g* (130)
b (010)	*e* (021)
c (001)	*u* (133)
m (110).	*n* (163)

The face *c*, is often missing or only slightly developed. The other faces are generally fairly equally shown. Three good examples are illustrated on Plate 39, figs. 5, 6, 7 and a clinographic projection on Plate 42, fig. 2.

The mineral is opaque even in the thinnest sections. Inclusions parallel to the direction of cleavage comprise quartz, monazite, felspar and a yellow mineral which reacts microchemically for uranium and may possibly be autunite.

The specific gravities of nine clean crystals are respectively 5·28, 5·3, 5·37, 5·41, 5·41, 5·42, 5·42, 5·44, 5·52 showing that the mineral falls well within the limits of the columbite species.

Apatite.

A single di-hexagonal crystal of apatite was found growing on a fragment of a monazite crystal (Plate 41, fig. 4). The apatite is completely encrusted with bright green scales of torbernite and was at first mistaken for beryl. The question was quickly settled by a chemical test. Apatite also occurs intergrown with monazite forming small semi-crystalline nodular masses in the felspar (Plate 41, fig. 1).

Microcline.

Two crystals of this felspar were found. One is flesh-red and the other pinkish. Although dull to the eye thin sections show them to be quite fresh and clear. The better preserved crystal is twinned on the Carlsbad law with *a* (100) as the composition face. The forms present are

b (010)
c (001)
m (110)

It is figured on Plate 39, fig. 8.

Commercial possibilities of the deposit.

Interesting as this occurrence is from a scientific point of view and the rarity of such an association of minerals in India, it seems advisable to emphasise the fact that no conclusions can be drawn as to the commercial prospects of a find of this kind. All the minerals

described come from one small prospecting pit in a pegmatite of some size and no definite run of the minerals has been established. Much more work is necessary, particularly in the sinking of prospecting pits, as, owing to the weathered condition of both the pitchblende and the monazite, they are apt to be overlooked in mere surface searching. It is also necessary to point out that there is little chance of mining monazite at a cost which will enable the product to compete with the extensive and more easily worked deposits on the coast of Travancore. There is no hope of finding concentrates in the stream-bed near Pichhli as the conditions there are in no way suitable.

I should like to thank my colleague Mr. C. S. Fox for much generous help and our artist for the care taken in the preparation of the photographs.

EXPLANATION OF PLATES.

PLATE 39.—Fig. 1. Pseudomorph in uranium ochre after uraninite. To the right of the large example is a smaller but similar crystal.

Fig. 2, Fig. 3, Fig. 4. Monazite crystals.

Fig. 5, Fig. 6, Fig. 7. Columbite crystals.

Fig. 8. Microcline crystal.

PLATE 40.—Fig. 1. Multiple twinning in monazite from Mysore. Crossed nicols. × 19.

Fig. 2. Zoned zircons from Abraki Pahar. Ordinary light. × 19.

PLATE 41.—Fig. 1. Intergrowth of monazite and apatite. Small crystals of monazite in a matrix of apatite. Reflected light. × 3.

Fig. 2. Monazite crystals showing parallel growth. The prominent face is *w* (101). Natural size.

Fig. 3. Interpenetration group of monazite crystals. Natural size.

Fig. 4. Dihexagonal crystal of apatite on monazite. Natural size.

Fig. 5. Contact photograph with a piece of pitchblende from Pichhli showing cracks filled with decomposition product.

PLATE 42.—Fig. 1. Clinographic projection of monazite. The face *r* has been transferred to the left hand to enable *u* and *e* to appear.

Fig. 2. Clinographic projection of columbite.

NATURAL GAS IN BITUMINOUS SALT FROM KOHAT. BY MURRAY STUART, D.Sc., *Assistant Superintendent, Geological Survey of India.* (With Plates 43 and 44.)

THE object of this short note is to place on record certain phenomena observed in connection with the bituminous salt of Kohat. This salt, which has already been mentioned in my report on the rock-salt deposits of the Punjab and Kohat,[1] occurs locally in the uppermost few feet of the rock-salt, generally in the form of salt-bitumen schist, though in some places the salt has recrystallized naturally into large crystals which, when held up to the light, show the bituminous matter arranged along what appear to be the original planes of schistosity.

Plate 43, fig. 1, shows a photograph (natural size) of bituminous salt from Malgin in eastern Kohat; the schistose nature of the salt is well seen, as is also the abrupt nature of the contact between the bands of black bituminous salt schist and the non-bituminous pale grey salt. Fig. 2 on the same plate shows a photograph, by transmitted light, of a portion of a crystal of recrystallized bituminous salt (twice natural size), and illustrates how the bituminous matter remains distributed through the crystal along what were the planes of schistosity in the original bitumen-salt schist.

My attention was drawn to the presence of natural gas in this recrystallized material by the fact that, when placed in water and allowed to dissolve, the salt gave off a continual stream of bubbles. I collected some of the gas and found it to be inflammable, burning with a practically non-luminous flame. As the amount of gas collected was surprisingly large, I made the following experiments to ascertain, as far as possible, how the gas is contained in the salt and what is the nature of the other inclusions.

Since the black bituminous contents of the salt-schist are by no means uniformly distributed, I selected, for the experiments, what appeared to be an average specimen of salt. The specific gravity, taken in a saturated brine prepared from the same salt, was found to be 2·49. A portion of a crystal of recrystallized bituminous salt,

[1] *Rec., Geol. Surv. Ind.*, Vol. L, p. 64.

similar to that illustrated in Plate 43, fig. 2, was weighed and then placed in distilled water, and the liberated gas collected in a graduated tube. The salt weighed 90·0 grammes, and the amount of gas collected was 19·5 c.c., the temperature at which the experiment was carried out being 30°. That is to say, a piece of a bituminous salt crystal having an approximate volume of 36 c.c. liberated, on solution in water, 19·5 c.c. of gas. In addition to the gas, a trace of oil appeared on the surface of the water, and a quantity of insoluble solid matter remained at the bottom of the vessel. The gas is colourless, and has a characteristic paraffin smell. On analysis in a Hempel apparatus, it was found to belong to the saturated hydrocarbon series (paraffins), and to contain no carbon dioxide, oxygen, unsaturated hydrocarbons, carbon monoxide, or nitrogen. It burned with only a slightly luminous flame. A test for sulphuretted hydrogen with lead acetate paper showed the presence of a small quantity of that gas; it is uncertain, however, whether this may not have come from the salt, as its presence is not rare in the salt of Kohat. In order to determine the amount and nature of the insoluble residue, a second piece of the re-crystallized bituminous salt crystal was weighed and dissolved on a filter paper by allowing water to drip slowly on it. In this way all the soluble matter passed away in the filtrate and the insoluble matter remained behind on the filter. This insoluble residue was dried at 100° C, weighed, and then treated successively with benzene, carbon disulphide and ether to dissolve out any bitumen, dried again at 100° C, and again weighed. As much of the final residue proved to be gypsum, it was not considered desirable to burn off the filter paper and ignite the residue before weighing, and the method of two counterbalanced filter papers was used, the second being subjected to exactly the same conditions as those to which the paper containing the residue was subjected. The result of the experiment was that 25·801 grammes of salt yielded 1·345 grammes of insoluble mineral matter and 0·08 grammes of bitumen. As stated above, the amount of oil liberated in the experiment is merely a film on the surface of the water. By dissolving a large quantity of salt, however, and then extracting this liberated oil, it was possible to obtain sufficient to test its boiling point. It began to distil over at 70° C, but nearly half its volume consisted of an oil distilling over between 250° and 300° C. The insoluble mineral residue consisted of minute highly angular quartz grains and fragments of selenite in about equal

proportions, together with some stony gypsum containing black bituminous matter. The average size of these angular grains of quartz and selenite was between ·07 mm. and ·036 mm. In addition to this fragmental matter, the residue contained one minute bipyramidal quartz crystal about 1 mm. long and two nearly perfect crystals of selenite, each about ½ mm. long.

In order to ascertain, if possible, how the gas is contained in the bituminous salt crystals, I took a photomicrograph, focussed into the centre of a crystal, with a magnification of 53 diameters. The result (Plate 44) shows minute bubbles of what appears to be liquified gas scattered through the salt. These bubbles do not seem to be necessarily associated with solid bitumen, but are scattered through the clear portions of the salt as well, probably, as with the black bitumen inclusions. This is further evidenced by the fact that the grey, non-bituminous salt-schist, where it adjoins the black bituminous layers, also contains this gas. It will be seen that in many cases the diameter of these bubbles is less than ·01 mm., and in only a few cases is it more than ·07 mm.; while the wide distribution of the bubbles probably accounts for the strong smell of paraffin noticed when a crystal of this bituminous salt is merely bruised. That these minute bubbles contain gas in a highly compressed and probably liquid form may be demonstrated by placing a dissolving crystal in a beaker of water and on a suitable sounding board, when, as the salt dissolves, the bubbles can be actually heard bursting their way out of the containing salt, and little bursts of bubbles may be seen, exploding out of the surface of the dissolving crystal as each report is heard. There can be no doubt that the gas is present in the salt under considerable pressure, sufficient probably, except in the case of methane, to convert it to the liquid state.[1] It is clear that the gas could not get into the salt in the gaseous state by sedimentary deposition, neither is it likely that it originated in it by a process analogous to the artificial "cracking" of saturated hydrocarbons, since it is found to contain no unsaturated hydrocarbons. There remain, therefore, two alternatives. The first, suggested by my colleague Dr. E. H. Pascoe, is that the *Ur*-material from which the gas and bitumen subsequently developed was contemporaneous with the salt, and that the bitumen and gas

[1] Methane would not, of course, be liquid, since the critical temperature of methane is considerably below the present temperature of the salt, but even so the gas would have a specific gravity comparable to that of a liquid.

are subsequent products of this contemporaneous *Ur*-material. The second alternative is that suggested in my report on the rock-salt of the Punjab and Kohat, *viz.*, that the occasional bituminous matter in the uppermost layers of the salt and the occasional bituminous matter incorporated in the gypsum immediately overlying the salt may be regarded as extraneous material caught up by and carried forward along the plane of an overthrust and incorporated in places into the uppermost layers of the salt.[1] This would mean that the salt was not the original home of the bitumen, oil and gas, but that they have escaped from their parent rock[2] along the overthrust and have been incorporated in places in the topmost layers of the salt schist immediately under the thrust-plane. Of these two alternatives I prefer the second. The first seems improbable, in view of the fact that the bituminous material occurs in small isolated patches in the uppermost few feet of the salt schist. These patches of bituminous salt schist are exceedingly scarce and occur in only a few exposures, notably at Malgin, Jatta and Nandrakka in eastern Kohat. They are generally associated with bituminous gypsum or with bituminous shales incorporated in the overlying gypsum. The salt itself is devoid of any indication of organic matter associated with it other than those few small patches of bituminous salt.[3] One is faced, therefore, with a discontinuous outcrop of salt schist and foliated salt extending from the frontier in Kohat to the Jhelum district in the Punjab, a distance of over 200 miles, showing no trace of organisms of any kind, but containing in its uppermost layers a very few[4] isolated patches of bituminous salt schist, each only a few cubic yards in volume. It seems unlikely that *Ur*-material would occur only in a few isolated patches of this kind in a length of salt stretching for over 200 miles if that material were contemporaneous with the salt and had been incorporated in it when the salt was first deposited. If *Ur*-material could and did exist in the saline water from which the salt was deposited, it should be fairly evenly distributed throughout the area of deposition, and not isolated in a very few minute patches. It seems more probable that the bituminous matter, oil and gas

[1] *Rec., Geol. Surv., Ind.*, Vol. L, pp. 84 & 91.

[2] Probably the nummulitic limestone or shales.

[3] This observation is confirmed by Wynne (*Mem., Geol. Surv. India,* XI, pt. 2, p. 44 and XIV, p. 84).

[4] Probably not more than five or six such patches are known to exist.

escaped from some other formation during the process of overthrusting, and that some of it became incorporated locally into the uppermost few feet of the salt schist, while some, together with bituminous shale, remained in the brecciated material along the line of the overthrust, being incorporated later in the gypsum sheet which formed along the overthrust plane. Petroleum is known to occur in the rocks which have in places been brought into contact with the salt by the postulated overthrust, and such incorporation of bituminous matter in the uppermost few feet of the salt schist seems not only possible but probable[1]. The above observations seem to confirm the conclusion already arrived at on other grounds and put forward in my report quoted above, that the paraffins and the bitumen are extraneous matter introduced into the uppermost few feet of the salt along the thrust-plane during the formation of an important overthrust. If this view is correct, it is probable that the gas occurs in the re-crystallized bituminous salt in practically the same state as that in which it existed in the oil-bearing rock from which it escaped during the overthrust; and since these crystals are transparent, they afford a valuable means of studying the state in which the gas actually occurs.

EXPLANATION OF PLATES.

PLATE 43.—Fig. 1. Bituminous salt schist from Malgin (Kohat). natural size.

Fig. 2. Portion of re-crystallized bituminous salt in transmitted light, twice natural size.

PLATE 44.—Photomicrograph of centre of crystal of re-crystallized bituminous salt, showing bubbles of liquid gas (× 53 diameters).

[1] As examples of petroleum occurring in formations which have in places been brought into contact with the salt by the overthrust, the following may be cited:—

(i) the oil issuing from the nummulitic limestone at Jaba (Wynne, *Mem., G. S. I.*, XIV, 264-5, 297);

(ii) the bituminous shale and clay included in the gypsum at Jatta (Wynne, *Mem., G. S. I.*, XI, 129).

THE MINERAL RESOURCES OF THE CENTRAL PROVINCES.

BY L. LEIGH FERMOR, O.B.E., D.SC., A.R.S.M., F.A.S.B., F.G.S., *Superintendent, Geological Survey of India.* (With Plate 45.)[1]

CONTENTS.

[1] This note, which has been written for the new edition of the Mining Manual of the Central Provinces and Berar, is also published here in order to render it more generally available.

I.—INTRODUCTION.

Geology.

THE geological formations hitherto identified in the Central Provinces are shown in the following list in order of increasing antiquity, the Dharwarian formations being, as far as is known the most ancient rocks identified not only in the Central Provinces but in India:—

Alluvium	Newer. Older.
Laterite.	
Deccan Trap with Intertrappeans.	
Lameta and other Infra-trappeans.	
Gondwana	Upper Gondwana. Lower Gondwana.
Purana	Upper Vindhyan. Lower Vindhyan (with ? the Sullavai series). Cuddapah (including the Bijawars and the Penganga series).
Archæan	Pegmatites, granites, gneissose granites, and basic intrusives. Schistose gneisses. Dharwarian formations—including Chilpi Ghat series, Sonakhan beds, Sonawani series, etc.

The foundations of the province are, of course, constructed of the various Archæan formations, which are exposed over a large portion of the province and build up many of the hill ranges. Furthermore, the structure of the Archæan complex has to a large extent determined the disposition of the later geological formations. In the northern portions of the province the average direction of the Archæan fold axes is E. to E.N.E., this being also the strike of the most important orographical feature, *viz.*, the Satpura range, built of Archæan rocks, covered at intervals by the lavas of the Deccan Trap formation, and extending as a geological entity at least as far east as Korea State and probably as far as Ranchi. Speaking generally, it separates the drainage of the Nerbudda and Son rivers on the north from that of the Godavari and Mahanadi on the south. The general strike of the Bijawars, Vindhyans and Gondwanas, as well as the alignment of the Nerbudda alluvial valley, also conform to this direction. In the southern portions of the province the average direction of the Archæan fold axes tends to be

N.N.E., *i.e.*, parallel to the Eastern Ghats, and certain Vindhyan and Cuddapah ranges also conform to this strike.

The N.E. and S.W. margins of the province are, however, bounded by terranes with a totally different strike, *viz.*, N.W., or at right angles to the average Archæan strike. This strike is exhibited by the Rampur (Raigarh-Hingir) coalfield on the north-east and by the Wardha valley and Godavari valley coalfields in the south-west. with, in the latter case, belts of Lower Vindhyan and Cuddapah rocks of the same average strike. Of a different type is the structure of the wide spread of Cuddapah rocks forming the gently dipping Chhattisgarh basin.

The wide-spreading flows of the Deccan Trap occupy nearly the whole of Berar, as well as wide stretches of the Satpuras, and give rise to the plateaus known as *pats* in Sarguja and Udaipur; this formation appears also as intrusive dykes and sills in various parts of the province, particularly in Korea State, where the dykes show the E.N.E. Archæan strike and where there is also an enormous doleritic sill intrusive in the Gondwanas and extending for many miles to the west into Rewah State in Central India. Immediately underlying the traps in many places are various Infra-trappean rocks, some of which (the limestones) are due to the replacing action of waters derived from the trap upon underlying gneisses and other rocks, whilst others are sedimentary sandstones and clays of Upper Cretaceous age. The Deccan Trap is apparently horizontal, but careful surveys show that there have been wide-spread post-trappean earth movements, causing gentle warping and dips and sometimes faults of considerable magnitude. Capping the Trap in many places, *e.g.*, in Seoni, Balaghat, Mandla, and on the *pats* of Sarguja and Udaipur, are roughly horizontal sheets of laterite occurring at altitudes of 2,000 to 3,500 feet above sea-level.

Finally, the majority of the rivers are bordered by strips of alluvium, amongst which two divisions may be detected: an older (probably Pleistocene) often rich in kankar, and now suffering denudation, in consequence of slight earth movements; and a newer (often darker) alluvium in process of formation at the present day. The wide-spread older alluvium of the Nerbudda and the Purna rivers appears to occupy basins formed as the result of gentle post-Deccan Trap warping of the Peninsula along an axis having a N.N.W. alignment. Finally, resting upon all the geological

formations are the recent soils varying greatly in character and fertility according to the underlying formation and ranging from the light sandy soils so often found on the crystalline rocks to the heavy black cotton soil characteristic of Berar and usually associated with the Deccan Trap.

Geological occurrence of mineral deposits.

The mineral resources might be discussed in two ways—either according to their mode of geological occurrence, or in alphabetical order. For general purposes the latter is the more convenient and will be followed here; but, in order to give an idea of the relative value of the various formations as sources of mineral wealth the following list has been compiled showing the mineral substances of possible economic value known to exist in each formation. Those substances that have proved in the past, or are likely to prove in the near future, to be of considerable economic value are shown in italics. From this list it will be seen that the most important formations from the mineral point of view are the Dharwars, with their deposits of manganese-ore, iron-ore, steatite, red ochre, limestone and dolomite; the Gondwanas, with their stores of coal, fire- and pottery-clays; the laterite, with its bauxite and building stone; and the alluvium with its supplies of brick-clays and kankar. Excellent building stones may be obtained from almost all the formations, as well as materials for the manufacture of cement, particularly in the Lower Vindhyans and Cuddapahs; and many minor mineral products may be developed in the future. Unfortunately, none of the pegmatite veins (with mica, quartz, and rose quartz) or mineral veins (with copper, lead, silver, wolfram, fluorspar, and barytes) hitherto discovered have proved to be of much value.

Mineral deposits classified according to geological formations.

ALLUVIUM—*Brick-clays, kankar*, salt, gold.

LATERITIC FORMATIONS—

LATERITE—*Bauxite, building-stone*, pyrolusite, iron-ore, ochre, diamonds.

LATERITOID—*Iron-ore*, manganese-ore, ochre.

DECCAN TRAP—*Building stone* (basalt), agate, carnelian, jasper, opal, rock-crystal, *soda* (*trona*), mineral waters, Iceland spar.

INFRA-TRAPPEAN ("LAMETA")—Limestone, manganese-ore.

GONDWANA—

UPPER—*Pottery clay,* fireclay, coal, jasper pebbles.

LOWER—*Coal, fireclay, sandstone,* pottery clay, iron-ore, manganese-ore.

VINDHYAN—

UPPER—*Sandstone,* limestone, lithographic stone, manganese-ore, lead-ore.

LOWER—*Limestone, fuller's earth, shale,* lithographic stone, sandstone, diamond.

BIJAWAR—Limestone, sandstone, jasper, iron-ore, lead-ore, silver.

CUDDAPAH—*Limestone,* lithographic stone.

PEGMATITES AND MINERAL VEINS CUTTING ARCHÆANS—Mica, quartz, rose quartz, fluorspar, barytes, wolfram and ores of copper, lead, silver and gold.

GRANITE—*Building stone.*

GNEISS—*Building stone.*

DHARWARIAN (including Chilpi Ghat and Sonakhan beds)—*Manganese-ore, iron-ore, limestone, dolomite, marble, ochre, steatite,* asbestos, jasper, garnet, opal, spinel.

Statistics of mineral production.

The relative importance of the various mineral industries hitherto established in the Central Provinces can be judged from the following table:—

Mineral Production of the Central Provinces from 1909 to 1918.

—	Average. 1909-13	1914	1915	1916	1917	1918
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Asbestos .	(1910) 3	—	—	—	7	13
Bauxite .	449	514	876	750	1,363	1,192
Clay . .	17,382	33,738	33,359	—	—	2,918
Coal . .	227,960	244,745	253,118	287,832	371,498	481,470
Corundum .	—	—	—	—	—	80
Fuller's earth .	100	109	139	179	334	218
Iron-ore . .	2,612	18,402	4,747	4,464	3,669	6,097
Laterite . .	—	—	16,445	—	—	—
Lead-ore .	—	3	7	7	—	3
Limestone and kankar	79,816	148,471	63,079	45,555	86,444	134,798
Manganese-ore.	488,485	564,890	399,215	558,828	517,841	438,628
Marble . .	—	—	—	143	—	—
Ochre . .	258	108	12	8	900	16
Steatite .	476	502	329	892	2,422	3,493
Wolfram .	1·3	—	—	1·3	—	—

To all students of the mineral resources of India LaTouche's "A Bibliography of Indian Geology and Physical Geography, with an Annotated Index of Minerals of Economic Value," issued by the Geological Survey of India in two parts in 1917 and 1918 respectively, must prove a standard work; and in compiling the following account of the mineral resources of the Central Provinces, I have drawn freely upon this work and upon the Quinquennial Review of Mineral Production in India published in Vol. LXVI of the *Records of the Geological Survey of India.* In this account I have judged it unnecessary to refer in detail to the original papers, as the full references can usually be obtained in LaTouche's Bibliography. But at the end I have given a bibliography of the more important papers dealing with the mineral resources of the Central Provinces.

II.—MINERAL DEPOSITS.

Aluminium-ore (Bauxite).

Some years ago it was discovered that many of the lateritic deposits of India are highly aluminous, such aluminous varieties being identical with bauxite. Field-work carried out since 1903 by the officers of the Geological Survey has revealed the existence of extensive deposits of this material in various parts of India, and chemical investigation in the Geological Survey Laboratory and at the Imperial Institute has shown that certain of the Indian bauxites compare very favourably with the Irish, French and American bauxites placed on the English market.

The richest areas yet discovered in India are the Baihir plateau in the Balaghat district and the neighbourhood of Katni in the Jubbulpore district, both in the Central Provinces. But valuable ores have also been found in other parts of India, as well as in the Sarguja and Jashpur States and in the Mandla and Seoni districts of the Central Provinces. The bauxites to which most attention has been up to the present devoted are those of Balaghat and Jubbulpore. Eight analyses of specimens and samples of the Balaghat bauxites have given results ranging between the following limits :—

	Per cent.
Al_2O_3	51·62 to 58·83
Fe_2O_3	2·70 to 10·58
TiO_2	6·22 to 13·76
SiO_2	0·05 to 2·65
H_2O	22·76 to 30·72
Moisture	0·40 to 1·14

corresponding to 71·2 to 80·8 per cent. of Al_2O_3 after calcination.

Two Katni bauxites gave the following analyses :—

	No. 1	No. 2
Al_2O_3	65·48	52·67
Fe_2O_3	3·77	7·04
TiO_2	11·61	7·51
SiO_2	0·38	1·26
H_2O	19·38	29·83

From these figures it will be seen that the Balaghat and Jubbulpore bauxites are of very high grade. There seems also to be little doubt that large quantities of this ore are available, and the commercial feasibility of making use of these deposits has consequently been under investigation for some years. There are three ways in which the Indian bauxites might be developed :—

(1) Simple export of the raw or calcined material to Europe or America for use in the alumina factories.

(2) Manufacture of pure alumina locally by extraction with alkali, and export of the pure oxide to European or American aluminium works.

(3) Manufacture of the metal in India.

The first proposal is impracticable on account of the low prices of raw bauxite at European ports (22*s.* to 23*s.* per ton was an ordinary pre-war price), whilst the third would involve a heavy capital outlay under untried conditions, and elaborate preliminary investigation before power works could be erected. The second proposal involves much smaller risks, and it has been found on investigation that there are no technical difficulties in the way of manufacturing alumina from Indian bauxites[1]; and in this connection it is of interest to note that the price obtained for manufactured alumina in England varied from £5-10-0 to £7-10-0 in pre-war years. Several concessions have been taken out for working the bauxites of the Central Provinces, in the practical investigation of which considerable progress has been made.

The occurrence of aluminous laterite at Tikari near Katni, Jubbulpore district, was first noticed by Mr. F. R. Mallet in 1883.[2]

[1] *Rec. Geol. Surv. Ind.*, XXV, p. 29 : XXXVI, p. 220.
[2] *Rec. Geol. Surv. Ind.*, XVI, p. 113.

Early in 1905, after the Geological Survey had drawn attention to the identity of aluminous laterites with bauxite, Mr. P. C. Dutt of Jubbulpore secured an exploring license over this area, and later prospecting licenses were taken out by Mr. Dutt and a syndicate formed by him called the Bombay Mining and Prospecting Syndicate, with Messrs. C. Macdonald & Co., of Bombay, as Managing Agents. The objects of this syndicate were varied, including the manufacture of hydrated alumina, alum and aluminium, of cement and lime, and of pottery, fire-bricks, etc., materials for all these purposes being found within the bauxite concessions.

In August, 1912, the Katni Cement and Industrial Company, Ltd., was floated to acquire the Katni properties of the above syndicate, including the bauxite deposits.

It is understood that investigations are now in progress concerning the feasibility of utilising the bauxites of this province for the manufacture of aluminium.

Asbestos.

Small quantities of crude asbestos have been won at Tumkhera Khurd in the Bhandara district, but the samples received by the Geological Survey of India were of very inferior quality. The mode of occurrence has not been investigated.

Barytes.

One of the copper lodes at Sleemanabad in the Jubbulpore district proved to be rich in barytes, and a wagon load of this was despatched to Calcutta about the year 1904 for use in the works of the Shalimar Paint, Colour and Varnish Co., Ltd. The quality was, however, found to be poor. This locality is, in any case, not likely to be of much value as a source of barytes unless it should prove feasible to work the lodes for their metalliferous contents.

Building Materials.

Materials suitable for building purposes occur in great variety and abundance throughout the province and in all the geological

formations. The alluvial tracts, not only of the Narbada, Purna, Wainganga, Kanhan and other big rivers, but also of many of the smaller streams, yield excellent brick-clays, whilst kankar is frequently abundant in the tracts of older alluvium. Laterite, as is well known, forms an excellent material for roads and culverts, and is abundant in some parts of the province, and its valuable variety, bauxite, has at times been unwittingly used for road-metal and building purposes (*e.g.*, in Balaghat). The Deccan Trap areas provide an excellent building stone, *viz.*, basalt (*e.g.* at Sitabaldi, on the Satpura branches of the Bengal-Nagpur Railway, and in many parts of Berar). The so-called Lameta or Infra-trappean limestone, cropping out from below the Deccan Trap in many parts of the province, *e.g.*, in the Satpuras and in Nagpur and Chanda (Karamgaon), constitutes an excellent ragstone, and has been successfully used for bridges on the Nagpur-Chhindwara branch of the Bengal-Nagpur Railway.

Turning next to the Gondwana formation, clay suitable for pottery purposes is quarried at Jubbulpore from the Jabalpur group of the Upper Gondwanas, whilst sandstones suitable for ashlar work and fine carving may be obtained from the Kamthi division of the Lower Gondwanas. Well-known localities are Bhutara hill and Isapur in the Chanda district, Silewada near Kamthi, Akhund in Nimar and Ellichpur in Amraoti. Fine white sandstones are quarried at Sirgora and Pathe in Betul from the Talchir stage.

The Vindhyan formation is a well-known source of good building stones, the red, yellow and buff sandstones used in so many of the famous buildings of Northern India being derived from various divisions of the Upper Vindhyans. In the Central Provinces, the Rewah group near Hoshangabad has yielded thin red sandstone flags for use as roofing tiles.

The Lower Vindhayan limestone of Katni has been quarried for some years by Messrs. Cook & Sons and others for lime-burning and building purposes, and is also now utilised by the Katni Cement and Industrial Co., Ltd., together with Lower Vindhyan shales, for the manufacture of cement. Similar materials are to be used by the newly-floated Central Provinces Portland Cement Co., Ltd., the works of which are also to be placed near Katni.

The Raipur limestones and underlying Chandarpur sandstones of the Chhattisgarh basin are variously régarded as of Lower Vindhyan and Cuddapah age, more probably the latter. The limestones are now being extensively used for building purposes; in particular, a dark bluish limestone from Sikosa in the Drug district has been used extensively for flooring in buildings at Nagpur. The Pem or Penganga limestones (Cuddapah) are said to yield good building stone in places in the Chanda district (at Kandara). Future investigation may prove the suitability of Chhattisgarh for the establishment of a cement industry based on the use of the Raipur limestone, with shale derived from one of the neighbouring coal-fields.

The building stones obtainable from the Bijawar formation are of inferior quality. The limestone has been used in the construction of temples at Khudia in Hoshangabad, but, owing to siliceous bands, is usually too hard to be worked with ease. The coarse sandstone of Chirakhan in the same district has been used for building the fort at Joga and temples in the neighbourhood. The red jaspers occurring in this formation might be used for ornamental purposes.

In the Archæan formations several excellent building and ornamental stones occur. The most valuable and beautiful is marble, often dolomitic, of Dharwarian age. The best known locality is the Marble Rocks in the Jubbulpore district, but numerous excellent marbles occur in the Betul, Chhindwara, Nagpur and Seoni districts. The most accessible localities are at Khorari in the Nagpur distrct, and in the Sausar tahsil of the Chhindwara district, where some beautifully marked serpentine marbles are found (*e.g.*, near Devi); but hitherto they have been used only for local railway culverts and bridges. In the Dharwar outcrops there are also bedded quartzites, *e.g.*, in the Ambagarh range in the Bhandara district. Such quartzites have been used in the forts at Ramtek and Ambagarh. Amongst the various phyllitic and schistose rocks of the Chilpi Ghat series, slabby rocks suitable for roofing and flooring could perhaps be discovered. In the Archæan tracts of the Central Provinces there are also wide stretches of gneiss and granite, many of which would form excellent polished ornamental stone, *e.g.*, the gneissose granite near Jubbulpore and in the Satpuras near Lamta on the Jubbulpore-Gondia branch of the Bengal-Nagpur Railway.

Coal.

The province contains over 30 coalfields, of which the following is a list:—

SATPURA AREA—

Narshingpur district—

1. Mohpani (8).

Betul district—

2. Lokartalai.
3. Shapur.

Chhindwara district—

4. Tawa R. (partly in Betul)
5. Kanhan R.
6. Hingladevi.
7. Barkui or Pench Valley.
8. Sirgora.

CHHATTISGARH & CHHATTISGARH FEUDATORIES—

Korea State—

9. Sanhat (part of Sohagpur field in Rewah).
10. Jhagrakhand do.
11. Kurasia (30-50)
12. Koreagarh.

Jhilmilli State—

13. Jhilmilli.

Sarguja State—

14. Ramkola-Tatapani (partly in Central India.
15. Panchbharni.
16. Bisrampur.
17. Bansar.
18. Lakhanpur (partly in Bilaspur).
19. Rampur.

Bilaspur district—

20. Damhamunda (in Matin).
21. Sendurgar (in Matin).
22. Lapha (part of the Korba field).
23. Korba.

CHHATTISGARH & CHHATTISGARH FEUDATORIES—*contd.*

Udaipur State—

24. Mand R.

Raigarh State—

25. Raigarh-Hingir (Rampur), partly in Bihar & Orissa.

WARDHA VALLEY GROUP—

Chanda district—

26. Bandar.
27. Warora (14).
28. Ghugus (45).
29. Ballarpur (partly in Hyderabad) (36).

Yeotmal district—

30. Wun-Papur (50).
31. Wun (2,100).
32. Junara & Chicholi (partly in Chanda) (75).

Space will not permit an account of all these fields, for which references should be made to the "Coalfields of India" by V. Ball and R. R. Simpson.

All the above coalfields belong to the Barakar division of the Lower Gondwanas, but, in addition, coal has been found in Upper Gondwana rocks at Lameta Ghat and other localities in the Narbada valley; such coal has, however, never been considered worthy of exploitation except for local purposes, and will not be referred to further.

Considering now the Lower Gondwana coals of the Central Provinces, it may be said that, generally speaking, those hitherto worked have yielded coal of second- or third-class quality as compared with the best coals of Bihar and Orissa. Samples from some of the unworked fields, such as the Kurasia field in Korea State, show, however, that the province does possess coal of first-class quality, though usually in the less accessible parts. As regards quantity the amount of coal in some of these fields is very considerable, and, according to the estimate of Hughes, the fields of the Wardha valley contain 2,525 million tons of coal, of which 1,714

million tons is regarded as available: of this 1,500 million tons lies in the Wun field. In cases where estimates have been made, the quantities are indicated in millions by the figures placed after the names of the fields in the list given above.

In spite, however, of the existence of this large number of coal-fields, the majority have not been worked, partly owing to their situation as regards communications and partly on account of inferior quality. The Warora field, after being worked for 33 years as a Government colliery, was closed down in 1906, and replaced by the Ballarpur colliery, which was handed over to a private firm in 1913. The Mohpani field was first opened up in 1862 by the Nerbudda Coal & Iron Co., Ltd., and in 1904 was sold to the Great Indian Peninsular Railway. In the Pench Valley (Barkui) field, collieries have been at work since 1905, and this field is now served by both the Bengal-Nagpur Railway and the Great Indian Peninsular Railway; and, as will be seen from the figures given below, this field is now the chief producer in the Central Provinces. A colliery is also being opened out on the Ghugus field, where a pit was sunk and worked for a time as long ago as 1870. Prospecting operations are being conducted in the Kurasia field in Korea, to which it is proposed to construct a branch line from the Katni-Bilaspur Chord of the Bengal-Nagpur Railway. Coal is also being raised from the Raigarh-Hingir field, but from the portion situated in the Sambalpur district of Bihar and Orissa. The following figures show the output of coal from the coalfields of the Central Provinces during the years 1914-1918 :—

—	1914	1915	1916	1917	1918
	Tons.	Tons.	Tons.	Tons.	Tons.
Ballarpur . . .	89,292	94,880	48,889	95,303	135,375
Mohpani . . .	59,774	55,086	48,395	71,693	78,792
Pench Valley . . .	95,679	103,152	154,548	204,502	267,303
TOTAL .	244,745	253,118	287,832	371,498	481,470

The quality of the coals of the Central Provinces may be judged from the following selected table of analyses of coals from some of the best-known fields.

—	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	
Satpura coalfields—						Average of—
Mohpani, coal . .	2·52	24·26	48·71	24·01	0·50	10 samples.
do. splint .	2·84	20·55	37·42	38·24	0·95	
Barkui field . .	—	22·8	53·6	23·6	—	3 samples.
Barkui . . .	1·73	24·07	52·59	21·61	0·73	1 sample.
Sirgora . . .	—	28·0	61·6	10·4	—	
Chhattisgarh coalfields—						
Sanhat field, lower seam	5·70	28·22	44·80	21·19	—	3 samples.
do. upper do.	4·19	24·00	44·00	27·81	—	5 "
Kurasia field, Kurasia	8 66	30·92	48 86	11·50		6 "
do. Chirmiri	7·7	29·1	51·2	12·0	—	10 "
Bisrampur, Rer & Pasang rivers.	—	37·6	57·0	5·4	—	2 "
Bisrampur Mahan & Masan rivers	—	19·5	48·0	19·6	—	3 "
Lakhanpur (Parsa) .	7·50	28·70	50·90	12·90	—	5′ 6″ seam
Korba (Ghordewa) .	6·91	29·06	53·03	10·10	—	5′ seam (2 samples.)
Wardha Valley coalfields—						
Wun-Papur (Pisgaon).	—	19·4	63·9	16·7	—	2 samples.
Ghugus . . .	—	33·49	45·61	20·90	—	32 boring samples (32′ seam).
Ballarpur . . .	11·10	31·56	45·47	11·87	—	1 sample from boring core.

Copper-ore.

Copper-ores have been discovered at several localities but none of these occurrences has hitherto proved to be large enough for exploitation by modern methods. The best known occurrence is at Sleemanabad in the Jubbulpore district, where a series of veins up to 4 feet wide, and cutting across the strike of dolomites of Dharwarian age, were made the object of prolonged prospecting operations by Messrs. P. C. Dutt and Burn & Co. some years ago. The chief ores found were chalcopyrite, tetrahedrite, and galena, with barytes; and selected samples yielded up to 200 ounces of silver per ton. The lodes did not, however, prove to be large

enough nor sufficiently persistent to justify mining operations. Azurite and malachite with oxides of copper occur disseminated through schists regarded as of Bijawar, but more probably of Dharwar âge, at Birman Ghat on an island in the Narbada in Narsinghpur district. These ores were mined by the Narbada Coal and Iron Company some 45 years ago, and a certain quantity of the ore was sent to England, but the mine was ultimately abandoned. Several of the early samples yielded from 12·6 to 47·8 per cent. of copper, the average yield being 28 per cent. Incrustations of copper carbonates have been found in excavations on a quartz reef in the Chilpi Ghat series at Malanjkhandi in the Balaghat district, and also in the galena-quartz vein traversing the gneiss near Chicholi in the Drug district (see page 289).

Fire-clay.

Fireclay is often found in the Indian coal measures associated with coal-seams, frequently as an under-clay, and could probably be obtained from most of the coalfields of the Central Provinces if required. In particular, it has been noticed as a stratum 11′ 3″ thick above No. 2 seam at the Warora colliery. Some of the white Upper Gondwana clays of Jubbulpore are found to be exceedingly refractory and are used in Messrs. Burn & Co.'s and other local pottery works.

Fluor-spar.

Fluorite is found in small quantities in the galena-quartz vein at Chicholi in the Drug district, and has also been found in minute quantities in a vein of altered quartz-porphyry carrying copper- and lead-ores at Sleemanabad in the Jubbulpore district. Neither occurrence appears to be of any value as a source of fluor-spar.

Fuller's Earth.

This substance has been raised for some years from the Lower Vindhyan rocks at Katni, the average annual output for the 5 years (1914-1918) being 196 tons.

Gemstones.

Diamonds were formerly worked at Wairagarh in the Chanda district, but by 1843 the workings had been abandoned. The gems

are said to have been obtained from a lateritic grit, and it is suggested that the source of the diamonds was the Lower Vindhyan (?Cuddapah) rocks of this district. The geodes of the Deccan Trap formation are the source of many varieties of semi-precious stones, all of them forms of silica, such as agate, carnelian, onyx, jasper, amethyst, and rock crystal. These minerals are commonly found in rivers draining off the Deccan Trap, and their abundance in the bed of the Narbada has led to the establishment of an Indian lapidary industry at Jubbulpore, where many varieties of polished agate may be purchased. Although it is not a gemstone, yet it is convenient to mention here that crystal-clear pieces of calcite suitable for use as Iceland spar for optical purposes are sometimes found in geodes in the Deccan Trap. Such material would probably prove to have a considerable market value.

The Archæan rocks occasionally contain rose-quartz suitable for use as an ornamental stone, as at Khairi in the Chhindwara district. The crystalline limestones of this district sometimes carry a lilac-coloured spinel, which has not hitherto been found in gem quality, however.

Gold.

Alluvial gold has been obtained from time immemorial by local gold-washers or *jhoras* from the river-sands and gravels of the province, but there is no evidence that it exists anywhere in sufficient quantity to be worth exploitation by modern methods. Amongst the districts and states that have thus yielded alluvial gold are Balaghat, Bastar, Bhandara, Bilaspur, Jashpur, Mandla, Raipur, Seoni, and Udaipur. Such alluvial gold has probably been derived ultimately from the ancient Archæan rocks, but the only localities where gold has been obtained *in situ* are Sonakhan in the Bilaspur district, where a gold mine is said formerly to have existed, and Sleemanabad in the Jubbulpore district, where gold has been found in the copper-ores in quantities ranging up to 15 dwt. per ton.

Iron-ore.

Iron-ores are widely distributed throughout the province, which is now perhaps the chief home in India of iron-smelting in small

indigenous blast furnaces. The following table shows the number of furnaces at work during recent years:—

—	1909	1913	1917
Bilaspur	103	99	103
Balaghat	4	—	(a)
Chanda	9	20	(a)
Drug	56	40	52
Jubbulpore	26	29	(a)
Mandla	65	49	(a)
Narsinghpur	4	(a)	(a)
Raipur	230	181	157
Saugor	13	19	(a)
TOTAL	510	437	312

(a) No figures available.

Returns showing the quantity of iron produced in these furnaces are no longer available, but the average annual yield per furnace is only about 1½ tons. At one locality, Ghogra, in the Jubbulpore district, manganiferous iron-ore is smelted with production of a steely iron known as *kheri*.

The iron-ores are found in four geological formations, *viz.*, laterite, the Chikiala and Barakar divisions of the Gondwana, the Bijawar, and the Dharwar, of which the last is the most important to the modern smelter.

Lateritic ores are most abundant near Katni in the Jubbulpore district, but are also found in Drug, Saugor, Yeotmal and other districts. In the Jubbulpore district the lateritic ores are well seen at Bijori and in the Kanhwara hills; in the latter locality three bands of ore, ranging from 2 to 2½ feet thick, are estimated to contain 49 million tons of ore. One sample yielded 57·52 per cent. of iron and 0·76 per cent. of P_2O_5.

Further south in this district, the upturned edges of the Dharwar hematites are capped by lateritoid limonitic ores formed by replacement.

Brown and red hematite occur abundantly in the sandstones of the Chikiala stage in the valley of the Pranhita, and are smelted in native furnaces at Yemlapali in Hyderabad territory and at neighbouring localities in the Chanda district.

The ores of Barakar age occur as ironstone zones at two horizons in the Raigarh-Hingir coalfield in Raigarh State, being most abundant near Kodoloi.

Iron-ores are also found in the Bijawar rocks in Nimar, Hoshangabad and Narsinghpur. In the two former districts the ores are almost invariably hematite, obtained from breccias occurring in the Bijawar series near the junction with the Vindhyans, or from debris derived from the same rocks. There is no evidence that these ores exist in sufficient quantity to interest a modern smelter, although they have been largely used in the past by the native smelter.

Narsinghpur district.

At Omarpani near Tendukhera in the Narsinghpur district both hematite and limonite occur irregularly distributed in fissures and hollows among the Bijawar limestones and quartzites, and were formerly smelted extensively by indigenous methods. In 1855 to 1857 some 70 to 80 furnaces were at work with a production of about 140 tons of iron annually. This metal was of unusually good quality, and a portion of it was converted into steel by re-heating, hammering, rolling in burnt cow-dung, and plunging into water. No estimate of the quantity of ore available appears to have been made.

The most valuable and abundant of the Central Provinces iron-ores occur in the Dharwarian rocks, particularly in the Chanda, Drug, and Jubbulpore districts, but also in Bastar State. Magnetite has been reported from the Archæan tracts of Kenda zamindari, Bilaspur district.

Chanda district.

With the exception of the Chikiala ores referred to, the iron-ore deposits of the Chanda district are all situated in the Archæan tracts, where they form well-marked bands (possibly beds) usually associated with Dharwarian rocks. The ore is usually hematite associated with banded hematite-quartzites, but magnetite is sometimes present. At least ten separate deposits have been located, and although they have not yet been exhaustively prospected, there is little doubt that some of them are of large size. The two best known are Lohara, where the iron-ore forms a hill ⅜th of a mile long, 200 yards wide, and 120 feet

high, and has been traced for a further distance of 2½ miles; and Pipalgaon, where a very fine mass of red hematite has been located.

In 1875 unsuccessful experiments were made at Warora in smelting iron-ore from Lohara and Ratnapur with Warora coal and a few years later a scheme was proposed for the establishment of modern iron works at Durgapur on the Erai river to smelt the ores of Lohara and Pipalgaon with charcoal fuel, the suggested scale of production being 25,000 tons of pig iron annually. Nothing, however, resulted from this proposal, and the Lohara deposit is now leased to the Tata Iron & Steel Co., Ltd., and held in reserve, except when small quantities of this very low-phosphorus ore are required for special purposes at Jamshedpur. The quality of the Chanda ores can be judged from the following analyses:

—	Fe.	SiO_2.	S.	P.
Asola	65·99	3·89	—	—
Dewalgaon	61·2	11·04	—	—
	67·76	1·50	—	—
Lohara	69·21	0·82	0·012	0·005
Pipalgaon . . .	71·05	4·5	trace.	trace.
Poser	69·8	—	—	—
Ratnapur (limonite) . .	49·7	26·0 (insol.)	—	—

Drug district.

The occurrence of valuable iron-ores in parts of the Raipur district (now included in Drug) was not known until Mr. P. N. Bose briefly referred to the chief deposits in a paper published in the *Records, Geological Survey of India,* Vol. XX, page 167 (1887). The district having been explored again on behalf of Messrs. Tata, Sons & Co., by Mr. C. M. Weld, a large area in the Dondi-Lohara zamindari[1] in the western part of the district was taken up under prospecting license for detailed examination.

Iron-ores of the Drug district, C. P.

The iron-ores, on account of their resistance to weathering agents, stand up as conspicuous hillocks in the general peneplain. The most striking of these is the ridge which includes the Dhalli and Rajhara hills, extending for some 20 miles in a zigzag, almost continuous line, and rising to heights of sometimes 400 feet above the general level of the flat country around. The iron-ores are

[1] This portion of the Raipur district has been included in the new district of Drug.

associated with phyllites and are often of the usual type of banded quartz-iron-ore schists characteristic of the Dharwar system. But in places, thick masses, apparently lenticular in shape, are formed of comparatively pure hematite, and one of these in the Rajhara hills has been subjected to very careful examination by diamond drilling. The Rajhara mass was carefully sampled across the surface at each point selected for a drill hole, and the cores obtained were also analysed in lengths representing successive depths of 10 feet each from the surface, giving altogether 64 samples, which were assayed for iron, phosphorus, sulphur, silica, and manganese. The average results obtained for the surface samples were as follows: Fe, 66·35; P, 0·058; S, 0·108; SiO_2, 1·44; Mn. 0·151 per cent; while for the cores the averages were Fe, 68·56; P, 0·064; S, 0·071; SiO_2, 0·71; Mn, 0·175 per cent.

In this mass the prospecting operations thus proved the existence of 2½ million tons of ore carrying about 67·5 per cent. of iron and a phosphorus content slightly below the Bessemer limit. The quantity estimated is that which may be regarded as ore in sight, while almost certainly much larger quantities may be obtained by continuation of the ore-bodies beyond their proved depth. There are other large bodies of ore in this area which have not been examined in the same detail. These masses of hematite include small quantities of magnetite, but separate determinations of the iron in the ferric state have not been made in order to determine the relative proportions of the two minerals.

Jubbulpore district.

The iron-ores of the Jubbulpore district have long been famous, and although the native industry now exists on only a small scale, some of the localities such as Majhgaon near Sihora, are very accessible, so that the indigenous processes of iron smelting can be readily studied. A fine red ochre has been quarried for some years for paint manufacture at Jauli. The lateritic limonite deposits of this district have already been referred to. The hematite deposits, apparently interbedded with the Dharwar phyllites, had for years been supposed to be very rich, but prospecting operations conducted in this area by E. P. Martin and H. Louis have shown that while iron-ore is widely distributed, and the formations in which it occurs are prominent in the district, there are no rich ore-bodies of large size that could be relied on for the output necessary to maintain an important industry, and most of the ore, being in the form of soft micaceous

hematite, would be physically unfit in its natural condition for use in a blast furance. Generally, also, the ores in this district contain a proportion of phosphorus too high for acid Bessemer steel.

The following analyses, extracted from Messrs. Martin and Louis' report (*Agricultural Ledger*, Calcutta, 1904, No. 3), give an idea of the nature of the ore in the principal occurrences in the Jubbulpore district :—

—	Iron.	SiO_2.	S.	P.	Moisture.
I. Agaria hill. Lateritic cap covering most of the hill. 3 samples	57·58 56·85 45·67	7·28 8·17 13·90	0·02 0·02 0·03	0·125 0·125 0·187	0·45 0·67 0·69
Soft micaceous hematitic schists. Ore-layers only. 2 samples.	60·70 58·40	7·45 8·40	0·019 0·022	0·075 0·081	0·25 0·33
II. Agaria ridge. Bed of hematite 4 to 5 feet thick, dipping 50°.	50·07	11·37	0·036	0·074	0·44
III. Jauli. Soft banded hematite-quartz-schists. Picked samples.	64·67 54·64 65·50 55·22	3·70 16·05 3·37 17·32	0·027 0·033 0·032 0·030	0·023 0·200 0·110 0·053	0·30 0·48 0·33 0·21

The hematitic ores occur interbedded with Dharwar phyllites.

Near Sihora siliceous brown hematites were found, poorer in iron, but physically more suitable for the blast furnace, and in this area there occur patches of manganiferous iron-ore.[1] The following analyses were obtained from samples obtained at Mansakra (Silondi) near Sihora :—

—	Fe.	Mn.	SiO_2.	S.	P.	Moisture
Wider band	52·15	0·36	14·70	0·022	0·385	0·10
Narrower band	44·95	6·28	14·55	0·027	0·352	0·27
Manganiferous iron-ore .	24·45	21·47	19·60	0·022	0·163	0·80

The above ores occur as lateritoid replacement products on the upturned edges of the Dharwar hematite ores.

[1] Cf. *Rec., Geol. Surv. Ind.*, XVI, pp. 101-103, (1883) ; *Trans. Min. Geol. Inst. Ind.*, I, p. 99. (1906) and *Mem., Geol. Surv. Ind.*, XXXVII, pp. 814, 815, 821-823. (1909).

Lead and Silver.

Lead-ores have been located in several places in this province, but in no case have these occurrences been found to be of sufficient magnitude for exploitation by modern methods. As would be expected, the majority of these deposits are in Archæan rocks, but strings and nests of galena have been found in Lower Vindhyan limestone in the bed of the Mahanadi river near Padampur in the Bilaspur district, whilst some old excavations in the Bijawar limestone at Joga Khurd in the Hoshangabad district yielded a sample of limestone with disseminated galena carrying 21 ounces of silver to the ton of lead.

The other occurrences are in Archæan rocks. The most important deposit is probably that at Ranitalao near Chicholi in the Drug district, where a well-marked quartz-vein, ranging in width from 6 to 30 feet, has been traced for a distance of 1½ miles through gneiss. The vein contains both galena and fluorspar, but the proportion of galena to vein-stuff appears to be small. Specimens of ore yielded over 9 ounces of silver per ton of lead. A small output of lead-ore from this district was reported in the years 1914 to 1916, but it is not known whether the production was from the locality mentioned above.

Argentiferous galena also occurs in association with the copper-lodes of Sleemanabad in the Jubbulpore district, whilst fragments of galena have been found near Nimbha in the Nagpur district. Finally, galena has been recorded from two localities (Bhelaunda and Chirai Khurd) in Sarguja State.

Lignite.

In 1884, Mr. P. N. Bose described an occurrence of lignite in logs up to 6 inches in diamater embedded in alluvial peaty clay below the sand of the Karun river 3 miles south-west of Raipur. Similar deposits were said to occur at other localities in the same neighbourhood, and Mr. Bose concluded that the quantity available might be considerable. The composition was as follows (average of two samples):—

Moisture	16·70
Volatile matter	48·60
Fixed carbon	29·15
Ash	5·55
	100·00

Lithographic Stone.

The occurrence of stone suitable for lithographic purposes has been recorded from two localities in the province. The material from one source, *viz.*, the Raipur district, and therefore presumably a Cuddupah limestone, was formerly used at the Raipur jail press. The other locality is near Hatta in the valley of the Sonar river in Damoh district, where a thin-bedded compact limestone of Upper Vindhyan age is found. No trial of this stone appears, however, to have been made.

Manganese-ore.

Judged either from quantity or value of the annual production, the manganese-ore industry is the most important mineral industry of the province, which contains some of the finest manganese-ore deposits in the world. These deposits are associated with a series of rocks known as the gondite series, regarded as metamorphosed manganiferous sediments of Dharwar age and characterised by the presence of various manganiferous silicates, the most important of which are the manganese garnet, spessartite, and the manganese-pyroxene, rhodonite. The ore-bodies consist typically of braunite and psilomelane, occasionally with hollandite, vredenburgite and sitaparite, and occur as lenticular masses and bands intercalated in quartzites, schists, and gneisses of Archæan age. The rocks of the gondite series are developed typically in the Chhindwara, Nagpur, Bhandara and Balaghat districts (and to a small extent in Seoni); in the portion of the Balaghat district east of the Wainganga river the manganese-ore horizon occurs near the base of the Chilpi Ghat series, which is regarded as a less metamorphosed facies of the rocks to the west of the Wainganga. That a portion at least of these ores is of primary origin is proved by the occurrence in intrusive pegmatites of fragments of the invaded manganese-ore deposit.

Although the occurrence of manganese-ores in this province has been recorded on several occasions from 1829 onwards, it was not until 1899 that the first prospecting license was applied for in the Nagpur district, the first shipment taking place in 1900. Work commenced in the Balaghat district in 1901, in the Bhandara district in 1903, and in the Chhindwara district in 1906, and together these four districts have been responsible for practically the whole of the output of manganese-ore from this province up to date. In the first year, 1900, the production totalled 47,257 tons, rising to 351,880

tons in 1906 and 565,017 tons in 1907; thereafter it has averaged about 500,000 tons annually, the maximum production being 649,307 tons in 1913. Except for small quantities of this ore that have been smelted at Jamshedpur and Kulti with production of ferro-manganese, the whole of this ore is exported. The export values of the Central Provinces manganese-ore production since 1906 have fluctuated between £403,526 in 1909 and £1,363,648 in 1917, the highest pre-war total being £1,314,412 in 1907.

As an index to the large size of some of these deposits, the following table may be of interest:—

Total Production of Manganese-Ore from certain Central Provinces Manganese-Ore Deposits.

Mine	District.	Year of commencement of work.	Total production to end of 1918.
			Tons.
Balaghat	Balaghat.	1901	1,069,192
Kandri	Nagpur.	1900	670,281
Chikhla (with Yedarbuchi)	Bhandara.	1901	638,196
Thirori	Balaghat.	1902	503,194
Kachi Dhana	Chhindwara	1906	441,740
Mansar	Nagpur.	1900	438,023
Lohdongri	do.	1900	268,161
Kodegaon	do.	1903	214,219
Miragpur	Bhandara.	1905	199,976
Sukli	do.	1905	191,620
Gumgaon	Nagpur.	1901	184,560
Ukua (with Gudma and Samnapur)	Balaghat.	1906	135,891
Kosumba	Bhandara.	1905	107,161
Junawani	Nagpur.	1906	102,167
Shodan Hurki	Balaghat.	1912	105,783
Ramrama	do.	1906	103,853
Kacharwahi	Nagpur.	1902	103,901

The quality of the manganese-ores from these four districts may be judged from the following figures :—

Range of Analyses of Manganese-Ores from the gonditic deposits of the Central Provinces.

—	Balaghat.	Bhandara.	Chhindwara.	Nagpur.
Number of analyses.	13	13	9	30
Manganese . .	49·08—54·51	49·00—54·07	48·95—54·97	42·28—56·52
Iron . . .	5·28— 9·10	3·86—10·25	5·00—11·77	2·09—16·34
Silica . . .	1·62— 6·02	2·08— 6·50	4·98—10·63	2·90—18·48
Phosphorus . .	0·04— 0·24	0·06— 03·4	0·06— 0·28	0·04— 0·65
Moisture . .	0·12— 0·85	0·09— 1·00	0·00— 1·27	0·11— 1·32

Means of above analyses.

—	Balaghat.	Bhandara.	Chhindwara.	Nagpur.
Number of analyses.	13	13	8	30
Manganese . .	51·88	51·94	52·72	51·53
Iron . . .	7·40	7·27	7·08	6·24
Silica . . .	3·74	4·59	7·16	7·25
Phosphorus . .	0·11	0·14	0·11	0·215
Moisture . .	0·37	0·44	0·38	0·49

The above samples were taken at or close to the surface, and deeper working is revealing a tendency towards a progressive increase of phosphorus contents with depth.

For information as to costs of working and other economic conditions, reference should be made to pages 135 to 169 of *Records* Vol. XLVI, (1913).

In addition to the gonditic areas referred to above, relatively unimportant manganese-ore deposits are found near Sihora and Gosalpur in the Jubbulpore district on the outcrops of rocks of Dharwar age, associated with the latter in such a manner as to leave little doubt that the ores have been formed by the replacement at the surface of Dharwar phyllites and quartzites. The masses of ore thus formed do not consist entirely of manganese-ore, but

often contain considerable quantities of iron-ore; and every gradation is to be found from manganese-ores through ferruginous manganese-ores and manganiferous iron-ores, to iron-ores. The masses of ore thus formed are often more or less cavernous and bear considerable resemblance to ordinary laterite and have in consequence been called lateritoid ores. The mineral composition of the ores thus formed is usually fairly simple. The manganese-ores are pyrolusite, psilomelane, and wad, whilst the iron ores are limonite and earthy hematite. Chemically, these lateritoid ores show a greater range of composition than the gonditic ores. The manganese is usually relatively low, so that the ores won consist mainly of second-grade manganese-ores and third-grade ferruginous manganese-ores. Such deposits would be worked to the greatest advantage if a market could be found for the iron-ores and manganiferous iron-ores, as well as for the manganese-ores. The ores of this district are of little value economically, but there has been a small output of recent years, possibly for special purposes:—

	Tons.
1907	7,100
1908	48
1910	300
1915	11
1916	576
1917	300
1918	65

The quality of the ores available is shown by the following analyses:—

—	MANGANESE-ORE.		MANGANIFEROUS IRON-ORE.	
	Range.	Mean.	Range.	Mean.
Number of analyses.	3	3	7	7
Manganese	34·53—56·80	45·56	6·20—25·60	20·26
Iron	1·60—10·30	4·79	19·17—47·10	28·78
Silica	1·40— 4·79	2·68	4·40—25·40	12·99
Phosphorus	0·03— 0·46	0·215	0·02— 0·85	0·25
Moisture	0·39— 0·90	0·56	0·12— 0·65	—

Two occurrences of manganese-ore at Ratanpur and Gorakona in the Bilaspur district, consist of pyrolusite, psilomelane, and wad,

formed by the replacement of rocks mapped as belonging to the Chilpi Ghat series.

In addition to the occurrences referred to above, manganese-ores of no economic significance have been found in several other districts. Impure wad has been found at Sontulai in the Hoshangabad district associated with rocks of presumed Bijawar age. In the Chandgarh and Harsud tahsils of the Nimar district four occurrences are known associated with four different geological formations, *viz.*, Bijawar, Vindhyan, Lameta and Deccan Trap, and, except the last, are probably examples of surface impregnation and replacement, and are of no economic value. In the Yeotmal district, manganiferous sandstone and nodules of manganese-ore in red clay, both of Lower Gondwana age but of no value, have been found.

Mica.

In the Central Provinces pegmatitic rocks abound, but although a certain amount of attention has been given to mica by prospectors, no deposits worth exploitation have yet been located. The largest plates hitherto discovered were obtained from Jungani in Bastar State and measured 4 to 5 inches across, but they were weathered and damaged by gliding planes. Attempts to work mica have also been made at Chitadongri and Bamni in the Balaghat district and at Komochoki in Bilaspur district.

Mineral Waters.

Although India is endowed with a large number of thermal and medicinal springs, yet no attempt has been made by modern enterprise to turn these resources to account. In the Central Provinces the following springs are known :—

District.	Locality.	Situation.	Temperature.	Properties.
Chhindwara . .	Anhoni . .	Trap dyke .	134°F.	Sulphurous.
Hoshangabad . .	Anhoni Samoni	Trap dyke .	114°F.	Sulphuretted hydrogen.
Sarguja . . .	Tat pani .	Line of fracture	136°–190°F.	Sulphuretted hydrogen & deposits siliceous sinter.
Yeotmal . . .	Khaur . .	—	87°F.	Deposits calcareous tufa.

Ochre.

Both red and yellow ochres occur at several localities in the province, and for many years there has been a small industry for the manufacture of paint from the red ochre mined at Jauli in the Jubbulpore district. The occurrence is in rocks of Dharwar age.

Red ochre is also obtained in the Gandai and Thakurtola zamindaries in the Drug district and in the Salitekri hills in the Balaghat district—in all cases probably from the Chilpi Ghat series, the local form of the Dharwars.

Yellow ochres are said to be found in the Chanda district and near Kalmeshwar in the Nagpur district.

Both red and yellow ochres are used locally for colouring houses, whilst the red ochre is also used for dyeing the clothes of particular castes.

Salt.

In the valley of the Purna river in Berar, there was formerly a salt industry dependent upon brine obtained from wells sunk in the alluvium, the brine being found at a depth of 90 to 120 feet with a head of 15 to 20 feet. The brine was evaporated by solar heat in shallow pans. The centre of the industry was Dahihanda in the Akot tahsil of the Akola district. In 1885-86 there were four hundred wells, yielding to Government a revenue of Rs. 21,000; each well produced about 20 maunds of salt per mensem.

A certain quantity of salt is obtained as a bye-product in the manufacture of carbonate of soda from the brine of the Lonar lake in the Buldana district of Berar. It has also been noted that beneath the alluvial deposits of Western Chanda is a deposit of saliferous sand or clayey sandstone. The salt appears as an efflorescence, and two samples gave an average of 85·23 per cent. NaCl and 13·94 per cent. $MgSO_4$.

Soda.

In the Deccan Trap basalts near the village of Lonar, in the Buldana district, Berar, is a circular crateriform hollow 300 feet deep and about a mile in diameter, and probably of volcanic origin, although views differ as to its exact mode of formation. This hollow is occupied by a shallow lake, the waters of which contain a large proportion of carbonates of soda, which crystallise out on the evaporation of the lake during the hot season and are used in the manufacture of glass and soap. According to one estimate, in March,

1910, when the maximum depth of the lake was 2 feet, the water contained 2,000 metric tons of sodium carbonate, whilst the upper layer of the lake mud to a depth of 1·5 metres contained about 4,500 tons. Six varieties of salt are prepared of the following range of composition :—

	Per cent.
Na_2CO_3	. 46·90 to 11·67
$NaHCO_3$	. 33·18 to 8·58
NaCl	. *nil* to 71·11

The ratio of carbonate to bicarbonate corresponds closely to that for the mineral trona or urao.

The rights to work the lake are let out on short-period contracts, and the output from 1909 to 1913 was about 450 tons.

The occurrence of *reh* at Paunar in the Wardha district has been noticed. It is used for washing clothes and making soap.

Steatite.

Steatite (talc, soapstone, potstone) has been found at several localities in the Central Provinces, usually in the Archæan terrane. The best-known locality is the Marble Rocks near Jubbulpore, where the steatite forms steeply dipping pockets in the Dharwarian dolomites. This steatite is slightly schistose, and varies from white to pale sea-green in colour. The deposits yield several hundred tons of steatite annually (see page 272), and one of the concessionaires has established at Jubbulpore a special plant for grinding the mineral, which is marketed in the powdered form.

Potstone and steatitic schist—probably of Dharwarian age—have been reported from several localities in the Bhandara district, whilst at Jambal Ghat in the crystalline area of Chanda is a dark-coloured potstone formerly used for carving into idols and household vessels.

Soapstone has also been reported from near Wun; the geological association of this occurrence is unknown, but it must be with post-Archæan rocks.

Tungsten-ore.

The only known occurrence of wolfram in this province is that discovered at Agargaon in the Nagpur district in 1907. The wolfram occurs sparsely scattered in veins and stringers of quartz interbedded with mica-schists and tourmaline-schists of Dharwar age. The veins, however, are small, and the total amount of wolfram

obtained appears to have been some 3 or 4 tons. Traces of scheelite have been found in association with the wolfram.

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MISCELLANEOUS NOTE.

Note on Sipylite from the Nellore District, Madras Presidency.

During a recent visit to the Nellore Mica Belt I had an opportunity to look over a quantity of samarskite which had been obtained from the Sankara mine. (See *Rec. G. S. I.*, Vol. XLI, p. 210, 1911.) With the samarskite was a piece of a quite distinct mineral. I took this for further examination. More recently Mr. F. Gaston of Messrs. F. F. Chrestien & Co. has sent another specimen of the same mineral from the Ruzulapad Mica mine. The latter locality is about two miles north-west of Sankara and not far from the village of Orupalle. The two specimens agree in every respect and there is no doubt as to their identity.

The specific gravity is 4·89. The mineral is brittle and the fracture splintery and uneven. The lustre is resinous and almost splendent. The colour of small splinters and thin sections is a bright red-brown. The streak is cinnamon brown. There is one prominent cleavage. Neither of the specimens show any approach to crystal outline.

The powdered mineral is partially decomposed by hydrochloric acid and completely by concentrated sulphuric acid. A qualitative analysis has proved the presence of niobium, rare earths, iron, uranium, calcium and magnesium. Zirconium is probably present but the test was not conclusive.

The physical and chemical characters correspond very closely with those of the mineral *Sipylite*.

[G. H. TIPPER.]

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA

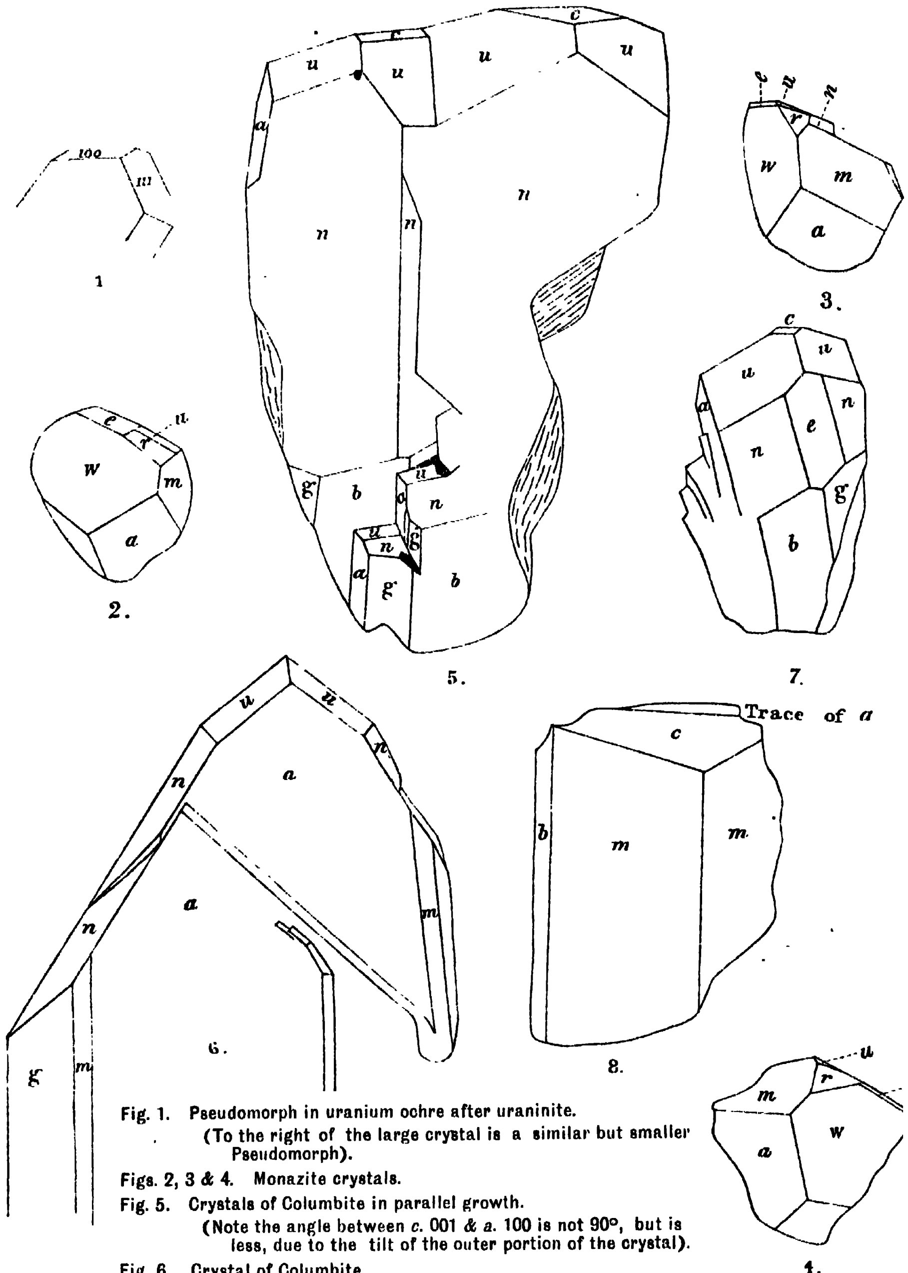


Fig. 1. Pseudomorph in uranium ochre after uraninite.
(To the right of the large crystal is a similar but smaller Pseudomorph).

Figs. 2, 3 & 4. Monazite crystals.

Fig. 5. Crystals of Columbite in parallel growth.
(Note the angle between *c*. 001 & *a*. 100 is not 90°, but is less, due to the tilt of the outer portion of the crystal).

Fig. 6. Crystal of Columbite.

Fig. 7. Do. showing curvature of the small side units.

Fig. 8. Crystal of Microcline.

(All figures natural size).



Photographs by K. F. Watkinson. *G. S. I. Calcutta*

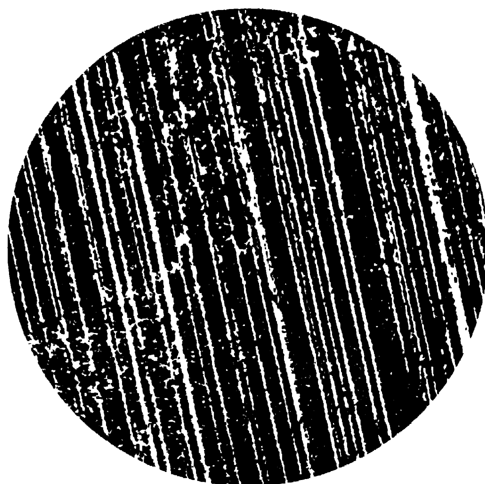


FIG. 1 MULTIPLE TWINNING IN MONAZITE FROM MYSORE
Crossed Nicols (× 19).



Photogravure by K. F. Watkinson. *G. S. I. Calcutta*

FIG. 2. ZONING IN ZIRCONS FROM ABRAKI PAHAR
Ordinary light (×19).

Explanation of Pl. 41.

Fig. 1. Intergrowth of monazite & apatite. Monazite crystals in a matrix of green apatite. (Reflected light × 3)

Fig. 2. Monazite crystals showing parallel growth. The prominent face is *w*. 101. (Natural size).

Fig. 3 Monazite crystals. Interpenetration group. (Natural size)

Fig. 4. Dihexagonal crystal of apatite on monazite („)

Fig. 5. Contact photograph with a piece of pitchblende from Pichhli showing cracks filled with decomposition produ



Photographs by K. F. Watkinson.

G. S. I. Calcutta

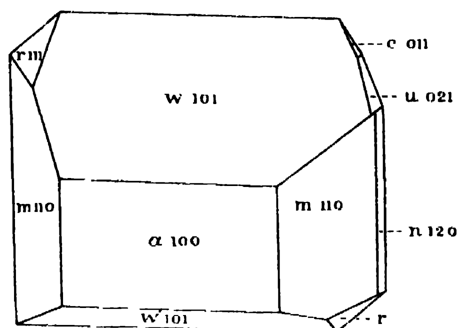
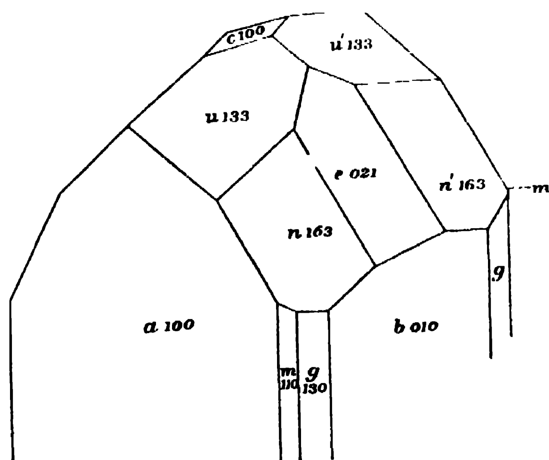


FIG. 1. CLINOGRAPHIC PROJECTION OF MONAZITE.



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FIG. 2. CLINOGRAPHIC PROJECTION OF COLUMBITE.

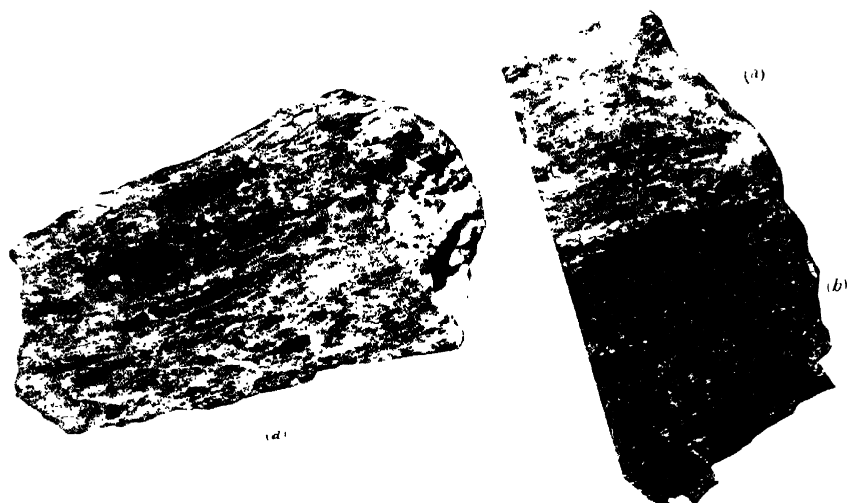
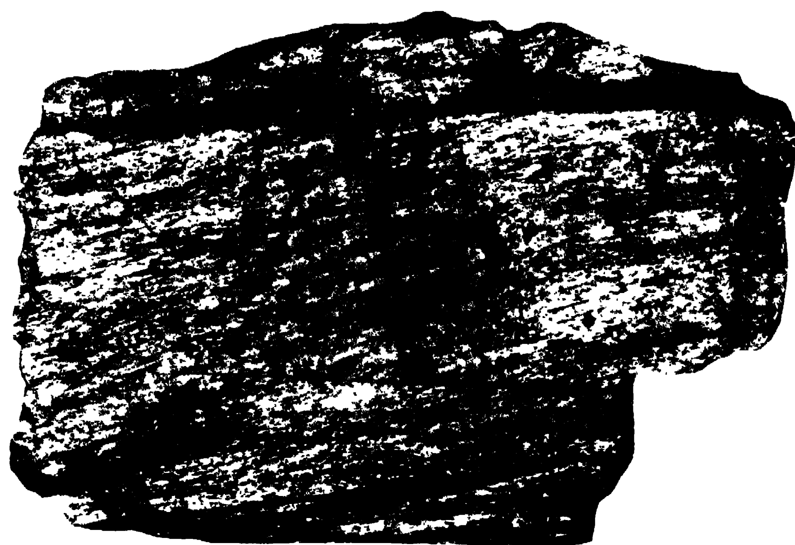


FIG. 1. PLANE POLISHED SURFACE OF SALT SCHIST.
(a) Grey, non-bituminous *(b)* Black bituminous. Photographs by reflected light.
(Natural size).

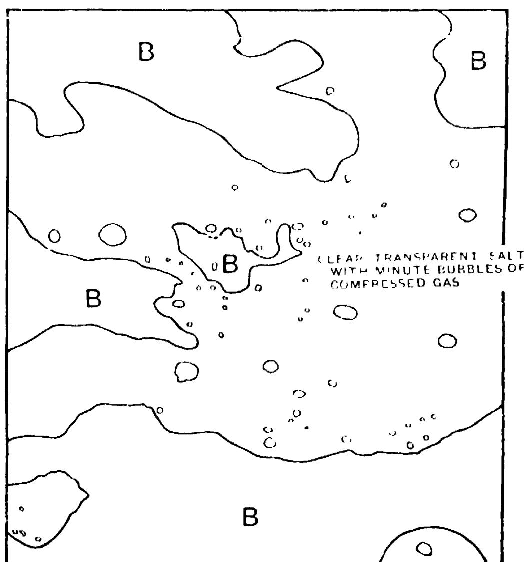


Photographs by K. F. Watkinson. *I. Cal*

FIG. 2. PORTION OF CRYSTAL OF NATURALLY RECRYSTALLIZED BITUMINOUS SALT.
Showing schistose arrangement of the bituminous matter through the crystal.
Photographed by transmitted light (× 2).



PHOTOMICROGRAPH OF THE CENTRE OF A CRYSTAL OF NATURALLY RECRYSTALLIZED BITUMINOUS SALT SHOWING MINUTE INCLUDED BUBBLES OF LIQUIFIED NATURAL GAS (Transmitted light × 53)



Photograph by Murray Stuart

G. S. I. Calcutta

KEY TO PHOTOMICROGRAPH. **B** – Bituminous Salt